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Child and Adult Mortality in Zimbabwe: 1980-2005

Double-Hugh Marera



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for the degree of Master of Philosophy in Demography
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PLAGIARISM DECLARATION

I, Double-Hugh Marera, hereby declare that the work on which this thesis is based is original, except where otherwise cited, and that neither whole nor any part of it has been submitted for another degree at this or any other university.

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ABSTRACT

This research applies direct and indirect methods to data from censuses and Demographic and Health Surveys to derive empirical estimates of the level and trends of child and adult mortality in Zimbabwe from 1980 to 2005. These mortality estimates are then compared to the United Nations Population Division (UNPD) estimates and projections as well as estimates from other sources.

Direct estimates of child mortality were reproduced by using the full birth history method used by Macro International to produce estimates from Demographic and Health Surveys (DHS) data. Indirect estimates of child mortality were derived from the Children Ever Born/Children Surviving (CEB/CS) method with an adjustment for bias caused by the mother to child transmission of HIV/AIDS. Brass General Standard, UNPD and INDEPTH life tables were used in deciding child mortality rates. The results show declining child mortality in the period 1980 to 1988 followed by a reversal of the gains from 1988 to early 2000s when child mortality started declining again.

Direct estimates of adult mortality were also reproduced using the direct sibling history method used by Macro International to produce estimates from DHS data. INDEPTH life tables were then used to convert the rates to standard measures. The Generalised Growth Balance method (incorporating migration following the method used by Dorrington, Timæus and Gregson (Dorrington, Timæus and Gregson 2006)) was used to estimate the relative coverage of the censuses which are then adjusted and used as input in the Synthetic Extinct Generations method to produce adult mortality rates. Estimates of adult mortality were also derived using the orphanhood method following the approach used by Timæus and Jasseh (2004) to minimise bias due to HIV/AIDS. Brass General Standard and INDEPTH life tables were used to convert the mortality estimates to standard measures. The results suggest a trend of increasing adult mortality between 1980 and 2005. Overall, the trends in both child and adult mortality are indisputable. However, the levels of mortality vary considerably.

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1 INTRODUCTION

The advent of HIV/AIDS in the early 1980s raised some important questions, not least: How much of the current mortality could be attributable to HIV/AIDS or non-HIV causes? This led to heightened interest among researchers and policymakers alike, in order to try and understand the epidemic and mortality, in particular. Mortality research in Zimbabwe, thus, has a very strong HIV/AIDS bias (Feeney 2001; Gregson, Anderson, Ndlovu *et al.* 1997; Hargrove and Humphrey 2010; Lopman, Barnabas, Hallett *et al.* 2006).

As with other developing countries, mortality estimation in Zimbabwe is hampered by the lack of a functioning vital registration system. However, data are available from censuses and surveys from which mortality estimates can be derived. The process of estimating mortality is never an exact science. It often involves triangulating the estimates of mortality that are produced by a number of techniques before deciding on the most robust estimates.

The standard methods, such as those published in the United Nations manuals (United Nations 1983, 2002), make some fairly strong assumptions about the scenarios under which they can be used. A common assumption on estimating child mortality is that mortality of mothers and that of their children are independent or that of siblings are independent. This is rarely the case in countries with generalised epidemics (Hallett, Gregson, Kurwa *et al.* 2010; Mahy 2003). Some of these methods need to be adapted before they can be used for countries with generalised epidemics.

This research analyses published national data to derive the level and trends of mortality in Zimbabwe over the period 1980 to 2005. It involves applying the standard methods to the different data sources available and then comparing the best estimates to those produced by the United Nations Population Division.

1.1 Research Question

Are the estimated levels and trends of mortality in the most recent United Nations Population Division World Population Prospects (WPP 2008) estimates and projections consistent with the mortality experienced by Zimbabwe from 1980 to 2005?

1.1.1 Objectives

- To derive empirical estimates of mortality in the period from 1980 to 2005, using published data sources.
- To establish trends on the level of both child and adult mortality over the period.
- To compare the estimates to those produced by United Nations Population Division (UNPD) and comment on the consistency (or lack of it).

1.2 Reasons for undertaking the research

Mortality, fertility and migration are key components of the demographic accounting equation. It is important to understand the levels and trends of mortality for a number of reasons. First, mortality is an indicator of the health and wellbeing of a country. Analysis of mortality levels and trends thus highlight the changing health status in a country as well as provide a means of evaluating the health system. This means that measuring mortality as accurately as possible is necessary in order to inform policy. Second, death registration in Zimbabwe and in many of sub-Saharan countries is still incomplete and can not be relied on to produce usable estimates of mortality (Timæus and Jasseh 2004). It is important, therefore, to be able to apply available mortality estimation methods to come up with reliable estimates while ensuring that assumptions underlying their use are not violated. Third, in data poor settings, mathematical models are often required to make demographic projections. Reliable mortality estimates are thus required to calibrate these models.

In the case of Zimbabwe, there is a wide range of childhood and adult mortality estimates produced by various researchers. Some of these were done when little was known about the course of the HIV/AIDS epidemic. Discussion of these estimates forms part of the literature review. Model-based estimates and projections produced by UNPD rely on assumptions about background mortality and the course of HIV infection. These are updated on a regular basis. They, thus, provide a time series of estimates upon which comparisons can be made regarding the levels and trends of mortality in Zimbabwe.

The purpose of this research is to rework the “old” estimates in light of increased knowledge about the impact of HIV/AIDS (and its potential biases) and compare these “revised” estimates with those produced by UNPD. This research seeks to contribute towards the broader debate on mortality in Zimbabwe. Apart from the UNPD estimates

and projections, researchers have tended to concentrated on one of either child or adult mortality. This research seeks to estimate the levels and trends of both child and adult mortality in one paper. In addition, the research intends to show how some of the indirect methods can be used in a country with a generalised epidemic. Also, as most of the substantial research on adult mortality was done before the Demographic and Health Survey 2005 was available, research using this data set might provide useful insights on the levels and trends of mortality.

1.3 Chapter outline

The dissertation is structured as follows. Chapter 2 reviews the literature on methods of estimating mortality. It begins with a discussion of the methods used to estimate child mortality. It then goes on to discuss the methods used to estimate adult mortality. In addition, the chapter also reviews currently available research or estimates of child and adult mortality in Zimbabwe.

Chapter 3 starts with the description and discussion of data sources used to estimate child mortality. It then deals with the methods used (in this thesis) to estimate childhood mortality. At the core of the chapter is the estimation and presentation of the childhood mortality, separately for direct and indirect methods. The chapter ends with a comparison of these derived estimates and the UNPD estimates and projections.

Chapter 4 begins with the description and discussion of data sources used to estimate adult mortality. It then deals with methods (used in this dissertation) to estimate adult mortality. The next part presents and analyses of the estimates of adult mortality. The section ends with the comparison of the derived estimates with those by other researchers, including the UNPD estimates and projections.

Chapter 5 contains the discussion of key results, and the strengths and limitations of the research. This section ends with discussion of scope for further research.

2 LITERATURE REVIEW

This chapter has two broad sections. It begins with a literature review of the methods used to estimate mortality in countries with incomplete vital registration. It then goes on to describe the mortality estimates in Zimbabwe for the period 1980 to 2005.

2.1 Methods for estimating child mortality

Methods of estimating child mortality fall into two categories: direct and indirect. The direct approach involves dividing the recorded deaths for particular age(s) by the person years of exposure to the risk of dying. This would be the most reliable measure if one used completely reported deaths and an accurate estimate of the population. The direct method can be used with data from DHS surveys or deaths reported by households in censuses and surveys to provide estimates of child mortality (Rutstein and Rojas 2006). Indirect estimation techniques have been formulated to estimate levels of child mortality in developing nations where data are often deficient, by asking women of reproductive age questions about the number of children they have had and the number of children that have died. These methods include the Children Ever Born and Children Surviving method (CEB/CS) and an adaptation which can be used when fertility experience of cohorts is known (Brass and Coale 1968:237). The CEB/CS uses data on children ever born and children surviving from a census or survey to obtain child mortality in the recent past with reference to the census date. The method assumes fertility is constant. The variation of the method, which does not assume unchanging fertility, uses data from two censuses or surveys to produce estimates of child mortality that correspond to the period between the two surveys or censuses. Each one of them has some advantages over the other, in terms of robustness to data errors and underlying assumptions. The methods are as described below.

2.1.1 Direct method

The direct method is commonly used to estimate infant and under-five mortality rates from the Demographic and Health Survey (DHS) data as well as from some Multiple Indicators Survey data. According to Rutstein and Rojas (2006), there are three main approaches to direct estimation. These are the vital statistics approach, the true cohort life table approach and the synthetic cohort life table approach. A brief description of the methods follows below.

2.1.1.1 Vital statistics method

This method uses data recorded in vital registration systems to estimate child mortality. If the data are complete, infant mortality rate can be calculated from the vital data alone. This is done by dividing the number of deaths of children under one year by the numbers of births in the same period (Rutstein and Rojas 2006). Under-five mortality can not be derived from the vital data alone because an estimate of the person-years of the population exposed to the risk of dying is required and this requires the numbers in the population from the population register or censuses. In sub-Saharan Africa, the data are not available to use this method.

2.1.1.2 True cohort life table method

This approach tracks a specific cohort of births to estimate child mortality. The key aspect of the method is that, in order to estimate a particular mortality rate, all the children for which the rate is desired must have been fully exposed to the risk of dying and no recent births are included (Rutstein and Rojas 2006). An estimate of infant mortality is obtained by dividing the numbers of deaths under one year by the number of birth in that specific cohort. An estimate of under-five mortality is calculated as a proportion of children dead out of those born to that cohort. These rates reflect the cohort and do not give information about period rates and thus become more out of date if mortality is required for higher ages (Rutstein and Rojas 2006). The method is appealing to longitudinal surveys.

2.1.1.3 Synthetic cohort life table method

The third method is, perhaps, the most useful direct approach in countries with inadequate vital registration. The method is based on the assumption that, if mortality rates are constant over time, age specific death rates for children in a survey will be good estimators of the age specific death rates for real cohort of children (Preston, Heuveline and Guillot 2001; Rutstein and Rojas 2006). The method, as described here and used in Demographic and Health Surveys, requires data that are classified by the following completed age bands: 0, 1-2, 3-5, 6-11, 12-23, 24-35, 36-47 and 48-59 months (Rutstein and Rojas 2006). Infant mortality rate is calculated in two stages. First, probabilities of survival for children in the age segments 0, 1-2, 3-5 and 6-11 months are calculated. Second, cumulative survival probabilities are determined as the product of the individual survival probabilities and the result is subtracted from 1 and multiplied by 1000 in order to get the rate into common form (i.e. rate per thousand live births).

2.1.2 Brass's Children Ever Born/Children Surviving (CEB/CS)

The CEB/CS method, developed by Brass (1968), is an indirect method used to estimate childhood mortality in countries with inadequate or poor vital registration. The logic of the method is that the proportion of children dead classified by the five-year age groups of women can be converted into probabilities of dying at exact ages in childhood (Hill 1991). It is thus based on the insight that there exists a close relationship between the proportion of children dead reported by mothers by age and the life table measure, ${}_xq_0$ where ${}_xq_0$ is the probability of dying between birth and exact ages x .

The basic assumptions underlying the use of the CEB/CS method are that the mortality of women and the mortality of their children are independent, fertility and childhood mortality has been fairly constant in the recent past and that a suitable model life table is used to describe the child mortality pattern in question.

The method uses data derived from the following questions (also called Brass questions): "Of all the children you have ever born alive, how many are now living with you? How many are living elsewhere? And how many have died?" It can be used with data classified by duration of marriage, age of mother, and hypothetical cohort data.

Two main variants (the Trussell (1975) and the Palloni and Heligman (1985)) are commonly used today. The main difference between the two variants is in the model life tables used with them to derive probabilities, ${}_xq_0$. The Trussell version uses the Princeton Coale-Demeny model life tables while Palloni and Heligman uses the United Nations model life tables for developing countries (United Nations 1990). Choosing an appropriate model life table depends on which one closely agrees with the mortality data in question. The Princeton Coale-Demeny West model, which is recommended for use where there is no information to suggest otherwise, has in the past been used by Central Statistical Office (Central Statistical Office (CSO) [Zimbabwe] 1985). In addition, the Trussell multipliers have been preferred as they are based on a wider range of model simulations than Palloni and Heligman (Singh, Karunakara, Burnham and Hill 2004). The variant by Trussell is as explained below. The method in detail can be found in Manual X (United Nations 1983).

First one calculates the average parities of women and the proportion of dead children by the age group of the mother. Defining $CEB(i)$ to be the number of children ever born to women in five-year age group i and $FP(i)$ to be the number of women of age group i , the average parity in that age group is given by

$$P(i) = CEB(i) / FP(i)$$

The proportions of children reported dead are then

$$D(i) = CD(i) / CEB(i)$$

where $CD(i)$ is number of dead children reported by mothers in age band i .

Next one calculates the multipliers, $k(i)$, using coefficients which were derived from least squares regression to fit of mortality since birth and $D(i)$ using generated from model fertility schedules and Coale-Demeny life tables (United Nations 1990). Four sets of coefficients exist corresponding to the four different model life table families in the Coale-Demeny system. The equation for estimating the multipliers is given by

$$k(i) = a(i) + b(i)(P(1)/P(2)) + c(i)(P(2)/P(3))$$

where $a(i)$, $b(i)$ and $c(i)$ are the regression coefficients and $P(1)$, $P(2)$ and $P(3)$ are average parities of women corresponding to ages 15-19, 20-24 and 25-29 years respectively.

The estimated probabilities of dying from birth to age x , $q(x)$, are then obtained using

$$q(x) = k(i) * D(i)$$

where x represent the exact ages at death (1, 2, 3, 5, 10, 15 and 20 years) which correspond to the seven five-year age groups of women i (with ages 15-19 ($i=1$) through to ages 45-49 ($i=7$)) respectively. The value of x is not necessarily equal to that of i because x is related to the average age of the children of women in age group i .

The next step involves calculating the number of years before the survey that the estimates refer to, $t(i)$, for the probabilities of dying at exact age x , $q(x)$. These are given by

$$t(i) = e(i) + f(i)(P(1)/P(2)) + g(i)(P(2)/P(3))$$

where $e(i)$, $f(i)$ and $g(i)$ are the regression coefficients and $P(1)$, $P(2)$ and $P(3)$ are average parities of women corresponding to ages 15-19, 20-24 and 25-29 years respectively. The coefficients $e(i)$, $f(i)$ and $g(i)$ were derived using linear regression applied to model fertility schedules by Feeney and others under the assumption that the rate of change of mortality has been constant in the past (Feeney 1980; United Nations 1990). The actual points in time (or dates) to which the mortality rates refer are obtained by subtracting the values of $t(i)$ from the date of the survey.

The probabilities of dying at exact ages are then translated into a common child mortality measure in order to identify the trend in mortality over time. This process

involves first identifying the level (in the model life tables) for which the calculated $q(x)$ s refer to (usually via interpolation) and then converting the levels into common indices such as infant mortality rate (${}_1q_0$) and under-five mortality rate (${}_5q_0$).

2.1.2.1 *An adaptation to the CEB/CS used when fertility of true cohorts is known*

The original Brass CEB/CS method described above assumes that fertility has remained relatively constant over time. If fertility has been changing, the observed parity ratios used to estimate multipliers may not reflect the fertility experiences of the cohorts. The resulting child mortality rates might therefore be underestimated if fertility is falling. In Zimbabwe, fertility has been falling for the last four decades (Muhwava and Timæus 1996; Sayi 2009). Thus it is necessary to allow for this when deriving the estimates. The method described below takes into account fertility changes by using fertility experiences of cohorts to estimate the multipliers, $k(i)$.

This adaptation, developed by Brass (1968), makes use of the fertility experiences of cohorts to estimate child mortality between the two censuses. The method in detail is also described in the Manual X (United Nations 1983). The following data are required for the method: the number of children ever born by the five-year age groups of their mothers for two censuses (or surveys) five or ten years apart, the number of children dead, classified by five-year age group of their mothers for the most recent census, and total number of women in the child bearing age range (15-49), irrespective of their parity, classified by the five-year age groups for each of the censuses (or surveys) being considered.

The first step is to calculate the average parities of woman and the proportion of dead children at the latest census. Defining $CEB(i, j)$ to be the number of children ever born to women in five-year age group i , at census (or survey) j and $FP(i, j)$ to be the number of women of age group i , the average parity is given by

$$P(i, j) = CEB(i, j) / FP(i, j)$$

The proportions of children reported dead at the time of second census are then

$$D(i, 2) = CD(i, 2) / CEB(i, 2)$$

where $CD(i, 2)$ are numbers of dead children in five-year age bands reported in the second (or latest) census and $CEB(i, 2)$ are the numbers of children ever born in the second census.

Similar to the Brass CEB/CS method, the estimated probabilities of dying at exact age x in this method are given by

$$q(x) = k(i) * D(i,2)$$

where $D(i,2)$ are the observed proportions calculated from the second census and $k(i)$ are multipliers and x is the exact age at death (takes the values 1, 2, 3, 5, 10, 15 and 20 years). The multipliers are given by

$$k(i) = a(i) + b(i)P(i-2,1) / P(i,2)$$

where $a(i)$ and $b(i)$ are regression coefficients, $P(i-2,1)$ are average parities from the first census and $P(i,2)$ are average parities from the second census. The multipliers are estimated by means of equations the coefficients of which were derived from mortality data fitted to model fertility schedules using least-squares regression. The difference between these multipliers from those from the original method is that the adapted method uses the ratio of the same cohorts but at different time points where the original method uses the ratio of different cohorts.

The second step involves calculating the estimated probabilities of dying before age x , for the values. In order to interpret trends in mortality the number of years, $t(i)$, before the latest census to which the mortality rates refer, is given by

$$t(i) = e(i) + f(i)P(i-2,1) / P(i,2)$$

where $e(i)$ and $f(i)$ are coefficients, $P(i-2,1)$ are average parities from the first census and $P(i,2)$ are average parities from the second census. The coefficients are available in Manual X (United Nations 1983). The last step, as in the original method, involves converting the estimated $q(x)$ values into life table measures by interpolation.

2.1.2.2 *Impact of a generalized epidemic on the CEB/CS method*

The key assumption underlying the use of the abovementioned methods is that the mortality of mothers and that of their children is independent. This assumption is known to be violated in countries with generalised HIV epidemics (Mahy 2003; Ward and Zaba 2008). The deaths of children will be correlated with that of their mothers due to mother-to-child transmission of HIV and the associated high mortality due to HIV in both children and mothers. This means that child mortality might be understated as children of dead mothers, who experience higher than average mortality, will not be included. In addition, standard model life tables do not take into account the impact of HIV on mortality of children, and biases in the estimates are likely. In the face of these violations, the CEB/CS method can not be relied upon to give reliable estimates of child mortality in high HIV prevalence settings. However, the method can be adapted for use in generalised HIV settings.

Ward and Zaba (2008) argue that, provided one can assume that HIV incidence is constant over time and the population is stable, the biases introduced by HIV to the Brass CEB/CS method can be corrected for by adding correction factors to the estimates derived from the method without correction. Thus the true estimates of mortality, denoted by $q(z)^t$, in the population are then equal to:

$$q(z)^t = q(z)^e + n(z),$$

where $n(z)$ is the correction factor and $q(z)^e$ is the mortality rate estimate calculated from the usual Brass technique without correction for HIV. The correction factors are estimated by means of one of two regression models that are fitted to HIV prevalence in women. The basic regression model is defined by:

$$n(z) = aPREV + b(PREV)^2$$

where $PREV$ is the prevalence in women of childbearing age, expressed as a proportion, while the extended regression model is given by:

$$n(z) = aPREV + b(PREV)^2 + cPREV15,$$

where $PREV15$ is HIV prevalence in women aged 15-19 years, expressed as a proportion, and ' a ', ' b ' and ' c ' are parameters to be estimated by regression.

A number of simulations performed by Ward and Zaba (2008) with HIV prevalence of women of child-bearing age found that all the regression coefficients but ' b ' for the 15-19 years age group in the basic equation (which was significant at 5% level) were significant at the 1% level. They also investigated through simulations the errors in the corrected estimates of under-five mortality and found that the corrected estimates were within the 5 per cent of the true value for each of the seven quinquennial age groups and for a range in HIV prevalences.

The methods assume that mortality and HIV incidence have remained constant for some time. This is not usually the case, and certainly not the case in Zimbabwe. Child mortality has been rising since the late 1980s (Central Statistical Office (CSO) [Zimbabwe] and Macro International Inc. 2007). HIV prevalence rose to a peak in 2005 and has been declining since then (UNAIDS 2005). However, Darikwa (2009) suggests a way the method can be adapted to take into account changing HIV prevalence.

Darikwa (2009) argues that if mortality had been changing in the recent past there is a need to estimate some time location, say $t(i)$, to which the estimates from Ward and Zaba (2008) refer. The approach, which assumes that HIV does not impact on time locations significantly, replaces the prevalence at the time of the survey with prevalence

at the time to which the rate applies. The adjustments to the correction factors allow for a steady rise in HIV prevalence until just before the survey.

The method uses the number of births to women in five-year age groups as the weighting factor to estimate the prevalence at the time of birth. Defining C_y^{2006-x} to be the number of babies per woman x years before the survey for women aged y years at the time of the survey, the weighted average HIV prevalence at the time of the birth of their children for women aged y years is given by:

$$PREV(y) = \frac{\sum_{x=0}^{y-15} w_y^{2006-x} * PREV(2006-x)}{\sum_{x=0}^{y-15} w_y^{2006-x}}$$

where $w_y^{2006-x} = \frac{C_y^{2006-x}}{\sum_{x=0}^{y-15} C_y^{2006-x}}$ is the weight and $PREV(2006-x)$ is the HIV prevalence

for women aged 15-49 exactly x years before 2006 (Darikwa 2009). The formula above shows how the method can be used for a survey conducted in the year 2006. The method can be used for any year by replacing 2006 with the year of interest. The average HIV prevalence at the time of birth for the median age is used to represent the five-year age group of women. In order to obtain mortality estimates, the adjusted estimates are converted into period rates by using a life table that takes into account the impact of HIV at the time to which the rate apply (in his case he used rates from the ASSA2003 population projection model).

2.1.2.3 Brass Logit Method

The method developed by Brass (1971) relies on the assumption two life tables can be related by a linear transform of the logit of their respective probabilities. If $l(x)$ and $l_s(x)$ denotes two distinct life tables, where the latter is the standard, it is possible to obtain constants α and β such that

$$\log it(l(x)) = \alpha + \beta \log it(l_s(x))$$

where $\log it(a) = 0.5 \ln \left(\frac{1-a}{a} \right)$ and a is a life table. α varies the mortality level of the standard and β varies the slope of the standard. This relationship is very powerful for measuring mortality in data deficient settings because it enables the estimation of common mortality indices in countries where either life tables are not available or if they

are available, they do not yield plausible estimates. The approach allows the use of a model life table that resembles the mortality of that particular country to convert conditional survivorship probabilities into measures such as infant mortality and under-five mortality rates.

2.2 Methods for estimating adult mortality

If vital registration is complete, direct estimates of adult mortality can be calculated by dividing the number of deaths by the population at the middle of the year. However, registration systems in most sub-Saharan countries are still incomplete. Thus, without any adjustment, the data can not give reliable estimates of mortality. A number of indirect estimation methods have been developed for use in such settings (United Nations 2002). These methods are either based on the distribution of deaths by age or on the survivorship of parents or siblings. Death distribution methods, which compare recorded deaths with those estimated on the basis of the numbers in the population by age at two time points and by assuming level of completeness with respect to age, are able to provide the shape of mortality in a defined intersurvey (or intercensal) period. The orphanhood and sibling survivorship methods estimate conditional probabilities of survival which are then transformed into life table measures of adult mortality.

In this section, death distribution methods discussed are the General Growth Balance (GGB) method and Synthetic Extinct Generations (SEG). After this, the conditional survivorship methods covered are the Orphanhood method and the Sibling survivorship method.

2.2.1 General Growth Balance Method

The General Growth Balance (GGB) method proposed by Hill (1987), allows for estimation of completeness of death reporting as well as relative completeness of enumeration of two censuses. The method is well documented in the United Nations manual (United Nations 2002). The description of the method presented here closely follows that set out in the manual. The method assumes that the level of completeness of enumeration in the two censuses and completeness of death registration are invariant with age, at least for adult ages.

The General Growth Balance method, like its predecessor the Brass Growth Balance method, is based on the population balancing equation

$$P_2 = P_1 + B - D$$

where P_2 and P_1 denote populations at two time points, B represents the number of births, and D represents the number of deaths during the period between the time points. The above equation can be rewritten by making D the subject of the equation to obtain

$$D = P_1 - P_2 + B.$$

If the number of births is known, then equation above will give the number of deaths during the period. This equation is not particularly useful in situations where death registration is incomplete because births tend to be under-reported as well. However, the equation can be rewritten so that the balancing equation applies to the population aged a and older. The result is a modified form shown below

$$D(a+) = P_1(a+) - P_2(a+) + N(a)$$

where $P_1(a+)$ and $P_2(a+)$ denote the number of people age a and over in the population at times 1 and 2 respectively, $D(a+)$ represents the number of deaths in the period aged a and over, and $N(a)$ denotes the number of persons reaching exact age a . The equation above can be rewritten in the form

$$N(a) - [P_2(a+) - P_1(a+)] = D(a+)$$

and dividing each side by $PYL(a+)$, the number of person-years lived during the period by persons aged a and over, yields

$$N(a) / PYL(a+) - [P_2(a+) - P_1(a+)] / PYL(a+) = D(a+) / PYL(a+)$$

where $PYL(a+)$ can be estimated in various ways, for example by using the geometric average of the two populations multiplied by the length of the period in years, i.e.

$$PYL(a+) = t[P_1(a+)P_2(a+)]^{1/2}.$$

The equation above can be written in a tidier form as

$$n(a+) - r(a+) = d(a+)$$

where $n(a+)$, $r(a+)$ and $d(a+)$ represent corresponding components. $n(a+)$ represents the rate at which population turns or becomes age a and over, $r(a+)$ denotes the growth rate of the population aged a and over, and $d(a+)$ is the death rate of the population aged a and above, respectively.

If constants k_1 , k_2 and c are introduced as measures of completeness of the census enumerations and the reporting of deaths respectively, then denoting the observed values with an asterisk we have the following relationships:

$$P_1^*(a+) = k_1 P_1(a+) \text{ i.e. } P_1(a+) = P_1^*(a+) / k_1$$

$$P_2^*(a+) = k_2 P_2(a+) \text{ i.e. } P_2(a+) = P_2^*(a+) / k_2$$

$$D^*(a+) = c D(a+) \text{ i.e. } D(a+) = D^*(a+) / c$$

$$n^*(a+) = N^*(a) / PYL(a+)$$

Manipulating the observed values into the expressions for $n(a)$, $r(a+)$ and $d(a+)$ leads to the following equations:

$$n(a+) = n^*(a+)$$

$$r(a+) = r^*(a+) + (1/t) \ln(k_1 / k_2)$$

$$d(a+) = d^*(a+) [(k_1 k_2)^{1/2} / c].$$

Substituting the new expressions for $n(a+)$, $r(a+)$ and $d(a+)$ into equation above and simplifying gives

$$n^*(a+) - r^*(a+) = a + b d^*(a+)$$

with $a = \ln(k_1 / k_2) / t$ and $b = (k_1 k_2)^{1/2} / c$.

Thus regressing $n^*(a+) - r^*(a+)$ on $d^*(a+)$, the values for the slope b and intercept a can be found. $k_1 k_2$ is then derived from the ratio k_1 / k_2 assuming (for convenience) that the maximum value of k_i as 1. Back substitution of $k_1 k_2$ into the expression and manipulation leads to the estimate of completeness of death registration, c .

If the assumptions are not violated and death reporting is complete, then the level of completeness, c , should be equal to one. If death reporting is not complete, c indicates the level of completeness. However, in reality, the assumptions are usually violated thus it is necessary to assess the results before deciding on the completeness of death registration.

2.2.2 Synthetic Extinct Generations Method (SEG or Bennett-Horiuchi)

The method developed by Bennett and Horiuchi (1981, 1984) is a generalization of the work of Preston, Coale, Trussell and Weinstein (1980) and Preston and Coale (1982) who argued that the number of deaths by age in a life table can be inferred from that of deaths by age in a population by using intercensal age specific growth rates. The method, detailed in the UN manual on estimating adult mortality (United Nations 2002), is based on the insight that, in a closed population with perfect death registration, the population aged x at the time t is equal to the accumulation of deaths arising from that cohort after time t up to the time the cohort becomes extinct. This is represented as

$$N(x, t) = \int_0^{w-x} D(x+y, t+y) dy$$

where $N(x, t)$ denotes the number of people aged x at time t and $D(x, t)$ represents the number of deaths at exact age x at time t .

The method compares the estimate of $N(x, t)$ derived from the census, $N^*(x, t)$, with one derived from the reported deaths, $N^d(x, t)$. Both $N^*(x, t)$ and $N^d(x, t)$ are estimates of the same thing. If the reported deaths are complete, the ratios of $N^d(x, t)$ to $N^*(x, t)$ would be equal to one. If, however, the deaths are incomplete, the ratios would be different from one.

If $P_1(x, 5)$ and $P_2(x, 5)$ denotes population census estimates and $D(x, 5)$ represent the deaths in the intercensal period. The ratios can be represented as

$$c(x) = N^d(x, t) / N^*(x, t)$$

where $N^*(x, t) = 0.2t[P_1(x-5, 5)P_2(x, 5)]^{0.5}$ and $N^d(x, t)$ is estimated by the following equations (Bennett and Horiuchi 1981):

$N^d(x-5, 5) = N^d(x, 5)\exp[5r(x, 5)] + D(x-5, 5)\exp[2.5r(x, 5)]$ for all age groups but the open interval. The open interval is given by

$$N^d(x) = D(x+)\{\exp[r(x+)e(x)] - [r(x+)e(x)]^2 / 6\}$$

where $e(x)$ is the future expectation of life estimate for a person aged x years exactly and $r(x, 5) = (1/t)\ln(P_2(x, 5)/P_1(x, 5))$ is the population growth rate.

If the age distribution and deaths are completely reported and the population is closed to migration, the ratios, $c(x)$, will be close to one. If the age distribution is accurate, and population is closed to migration, but deaths are uniformly under-reported over all ages, the ratios will be constant and equal to the fraction of the deaths that are reported. Any variation from the average suggests violation of the assumptions.

In practice, the age distributions are subject to some error as are reported deaths. When applying the method, it is normal to consider the population aged 15 and above as one can not assume that deaths of children are reported to the same extent as those of adults. The level of completeness can be estimated as the median of the ratios, $c(x)$, over a range of ages greater than 15 but usually excluding the oldest ages. The oldest ages are often unreliable because of data errors and low population numbers.

2.2.3 Adaptation of the GGB and SEG methods for net migration

The conventional application of the death distribution methods assume, among other things, that the population is closed to migration. However, for situations where migration is non-negligible both the GGB and SEG approaches can be adapted to allow for net migration (Bhat 2002; Dorrington, Timæus and Gregson 2006; Hill and Queiroz 2010)

In the GGB method, net migration is accommodated by adding the rate of migrants aged a and above, $nm(a+)$, component to the original Brass growth balance equation, and the result is a modified GGB equation given by

$$n^*(a+) - r^*(a+) + nm(a+) = a + bd^*(a+).$$

Similarly, age specific net migration rates, $nm(x,5)$, can be accounted for in the SEG method by subtracting the net immigration rate from the growth rate (i.e. replace the growth rate $r(x,5)$ in the original SEG method with $r(x,5) - nm(x,5)$).

2.2.4 Sensitivity of the GGB and SEG methods to data errors

Indirect methods are based on certain assumptions about the nature of data errors and the population. In their usual formulation both the GGB and SEG methods assume that the population is closed to migration. However, both methods can be adapted to allow for migration (Dorrington, Timæus and Moultrie 2008; Hill and Queiroz 2004; Hill, You and Choi 2009). Other assumptions underlying the use of both GGB and SEG are: that there is no misreporting of age of either population or deaths and that the completeness of death reporting is invariant with age. The SEG further assumes that there is no change in census coverage. However, Bennett and Horiuchi (1981) show in an endnote how the method can be adapted to allow for differential completeness of census coverage. These assumptions may be violated in practice.

While research on the sensitivity of indirect estimation methods has been limited, it has nevertheless affirmed their usefulness. Work by Hill, You and Choi (2009) on sensitivity analysis of the GGB and SEG methods using simulated data errors and that of Dorrington, Timæus and Moultrie (2008) agree that both methods work well when errors in data are the ones for which the methods were developed although, they reached different conclusions as to which method would perform better in poor data settings, the differences were not material. Dorrington, Timæus and Moultrie (2008) point out that an “adapted” version of the SEG method that allowed for differential completeness of the censuses performed well in countries with generalised HIV epidemics.

2.2.5 Orphanhood method

The orphanhood method is an indirect technique used to estimate adult mortality. It has its origins from the earlier work of Lotka (1939) and Henry (1960). The method was developed by Brass and Hill (1973) and has been improved or adapted by others since then (Brass and Bamgboye 1981; Hill and Trussell 1977; Timæus 1991a, 1991b, 1992; Timæus and Nunn 1997).

It is based on the insight that the vital status of a parent at the time of the survey and the age of their child at the time of the survey provides information about the probability of adult survival. The method estimates life table survivorship probabilities from proportions of children in five-year age groups with mother alive (for female survivorship) or with father alive (for male survivorship).

Like most other indirect methods, the orphanhood method works well provided the underlying assumptions are not violated. The method assumes that mortality of the parents and that of their children is uncorrelated. In addition, it assumes that biases introduced by the use of parents with at least one surviving child only and exclusion of parents (or adults) without children will be sufficiently small, or cancel one another sufficiently, to ignore. A drawback of the method is that it suffers from bias related to the inclusion of non-biological parents, particularly mothers, as biological parents. This is called “the adoption effect” (Preston, Heuveline and Guillot 2001:237).

A detailed description of the method can be found in United Nations manual on estimating adult mortality (2002). The method makes use of the vital status of parents of children (i.e. whether or not the parents are alive), the age and sex of the child and the mean age of childbearing. For a cohort aged x at time t whose mothers (or fathers) were all aged y at the time of their births (or conception), the proportion of mothers (or fathers) alive represents a conditional probability of survival which approximates, say, the cohort survival, l_{y+x}/l_y , of those aged y at time $t-x$. The above logic can be applied to proportions of respondents with mothers (or fathers) alive in five-year age groups and the conditional probabilities of survival are given by l_{M+x}/l_M , where M is the average age of childbearing of the mothers (or fathers) and x is the mid-point of the age group. The conditional survival probabilities can then be expressed as a linear function of the mean age of childbearing of parents at the time of the children’s birth, M , and the proportion of persons with surviving parents (mothers or fathers). Regression analysis is used to estimate coefficients in the expression below. The estimates of survivorship probabilities can then be converted into common probabilities by the use of appropriate

life tables. Different regression equations are needed for males and females because the mean age of childbearing differs between the two, as men tend to marry wives younger than them (United Nations 2002). For females, the relationship is conditioned on women reaching the age of 25 years and is given by

$$l_{25+x}/l_{25} = a_0(x) + a_1(x)M + a_2(x)S(x-5,5)$$

where $a_0(x)$, $a_1(x)$, $a_2(x)$ are coefficients, M denotes the mean age of childbearing of mothers of children and $S(x-5,5)$ represents the proportion of children aged $x-5$ to x with mothers alive. For males, the relationship is conditioned on reaching the age of 35 years and is given by

$$l_{35+x}/l_{35} = a_0(x) + a_1(x)M + a_2(x)S(x-5,5) + a_3(x)S(x,5)$$

where $a_0(x)$, $a_1(x)$, $a_2(x)$ and $a_3(x)$ are coefficients, M denotes the mean age of fathers at the time of conception of the respondents, $S(x-5,5)$ represents the proportion of children aged $x-5$ to x groups whose fathers are alive and $S(x,5)$ denotes the proportion of children aged x to $x+5$ whose fathers are alive. The regression coefficients $a_0(x)$ to $a_3(x)$ for the equations are provided by Timæus (1992).

If mortality has been changing, there is the need to estimate a time location to which the estimates refer. Brass and Bamgboye (1981) showed that the time location, $t(N)$, can be approximated by

$$t(N) = (N/2)(1 - C(N))$$

where N is the mid point for the age group, and $C(N)$ is a correction factor for that age group. The correction factor is given by

$$C(N) = \ln(S(N))/3 + f(N+M) + 0.0037(27 - M)$$

where $S(N)$ represents the proportion of persons aged N whose mothers (or fathers) have survived, M denotes the mean age of these mothers (or fathers) at the time the persons in question were born and $f(N+M)$ is a standard function of age whose value is derived by interpolation.

2.2.5.1 Intersurvey orphanhood method

The original method described above uses data from a single census or survey. If data are available at two time periods, Zlotnik and Hill (1981) and Timæus (1986), suggest how mortality rates pertaining to the inter-survey period can be estimated. The logic is that if two surveys of the same population are conducted five years apart then the proportion of respondents whose parents are alive for each age group at the first survey

can be compared with the proportion of the same parents who are alive at the second survey. The approach assumes that mortality and migration of children is independent of their mothers' (or fathers') mortality.

Zlotnik and Hill (1981) point out that ratios of proportions of mothers (or fathers) alive at the two survey dates represent proportion of these parents surviving over intersurvey period. Two forms of the intersurvey method exist depending on the length of the interval. One is for when the length of the interval is exactly five years and the other is for any length. However, the latter form is likely to perform better when the length is greater than five years (United Nations 2002). The two forms are described, in order, below.

Defining $S_1(x,5)$ and $S_2(x,5)$ as the proportion of respondents aged x to $x+5$ whose mother is alive at the first and second surveys respectively. If the surveys are exactly five years apart, the proportions of respondents with mother (or father) alive, $S^*(x,5)$, for a synthetic cohort is given by the following two equations:

$$S^*(5,5) = \frac{S_1(5,5) + S_2(5,5)}{2} \text{ and } S^*(x,5) = \frac{S_2(x,5)}{S_1(x-5,5)} S^*(x-5,5)$$

where $x = 10, 15, \dots$. The first of the two equations above sets the proportion of children with mothers' (or fathers') alive for the age group 5-9 years to the average of the proportions from the first and second surveys. The subsequent age groups are

obtained by multiplying the previous age group proportions by the ratios $\frac{S_2(x,5)}{S_1(x-5,5)}$

which reflect mortality conditions over the intercensal period.

The estimation procedure described in the original orphanhood method is applied to the $S^*(x,5)$ values as if they were proportions with mothers surviving from a single census or survey, but all are applicable as at the middle of intersurvey period.

When the length of the interval between the surveys is not exactly five years, an adaptation of the intercensal survival method proposed by Preston and Bennett (1983) may be used. Instead of ratios used above, synthetic ratios are computed from

$$R(x,5) = \frac{S_2(x+5,5) \exp[2.5r(x+5,5)]}{S_1(x,5) \exp[-2.5r(x,5)]} \text{ where,}$$

$r(x,5) = \frac{1}{t} \ln \left(\frac{S_2(x,5)}{S_1(x,5)} \right)$, where t is the length of the intersurvey interval and the proportions of respondents with mother (or father) from the first and second surveys are as stated earlier.

The proportions with surviving mothers for the synthetic cohort with length of intercensal interval other five years is given by $S^*(x,5) = R(x,5)S^*(x-5,5)$ where $x = 10, 15, \dots$ and $S^*(5,5) = \frac{S_1(5,5) + S_2(5,5)}{2}$.

2.2.5.2 Adjustment for the impact of HIV/AIDS to orphanhood

An essential assumption underlying the use of the orphanhood method is that the mortality of children and that of their mothers is independent. This assumption is violated in HIV epidemics as vertical transmission of HIV can occur from mother to child. The adjustment to the maternal orphanhood method proposed by Timæus and Nunn (1997) takes into account the selection bias introduced by HIV/AIDS and gives a procedure for estimating life table survivorship for populations with generalised epidemics.

Timæus and Nunn (1997) identified the main sources of selection bias in the orphanhood method as the correlation between the mortality of children and that of mothers due to vertical transmission of HIV and change in fertility of HIV infected people. In addition, the coefficients used to convert the proportion of respondents with parents surviving into life table measures are not suitable in an HIV/AIDS epidemic.

Using data from Masaka District in Uganda, they derived correction factors for the biases and the adjusted proportion of respondents with mothers alive is given by

$${}_5S'_x = \left[1 - (1 - (1 - h)F) \times P \right] {}_5S_x,$$

where h is the probability of vertical transmission of HIV, F is fertility rate of HIV-positive mothers, P is sero-prevalence rate among women of childbearing age, $x = 10, \dots$ attending antenatal clinics and ${}_5S_x$ is the proportion of respondents with mother surviving from the original method. The equation to correct for bias in children aged 5 to 9 years is given by

$${}_5S'_x = \left[1 - \frac{(1 - (1 - h)F)}{2} \times P \right] {}_5S_x,$$

and is obtained by halving the correction factors. Timæus and Nunn (1997) simplified the equations above to

$${}_5S'_x = \frac{1 - 0.25P}{1 + 0.25P} {}_5S^*_x \approx (1 - 0.5P) {}_5S^*_x$$

and

$${}_5S'_5 = (1 - 0.25P) {}_5S^*_5,$$

respectively, when the antenatal sero-prevalence at the average time of birth of the respondents in each group is known. The above simplification is valid when the sero-prevalence rate is collected from antenatal clinics. If, however, the estimate of sero-prevalence, P^* , is from a population survey, Timæus and Nunn (1997) show that the equation for correcting bias will be given by

$${}_5S'_x = (1 - 0.4P^*) {}_5S^*_x.$$

This method for correcting bias assumes that fertility of infected woman is 20 per cent lower compared to the uninfected woman and also that vertical transmission rate is 25 per cent. The adjusted proportion of respondents whose mothers are alive is thus a function of the HIV prevalence at the time of birth and survival proportions from the original method (i.e. unadjusted). On the basis of some sensitivity analysis, Timæus and Nunn (1997) highlight that the method would be useful to estimate mortality rates conditional on reaching age 15 years. The method, as described above, is to be used to estimate maternal orphanhood estimates. Timæus and Nunn (1997) did not provide a method for correcting bias in the paternal orphanhood method. However, Timæus and Jasseh (2004) provided an adjustment that can be used to correct for biases in the paternal orphanhood method. They suggest, taking into account the probability of co-infection of male partners of infected women, a reduction of 60 per cent of the correction factors used in maternal orphanhood method.

2.2.6 Sibling survivorship method

The sibling survivorship method arises from the work of Brass (1968). The method is based on the idea that the survival of one's sibling is good estimator of the survival to the respondent's age (Graham, Brass and Snow 1989; United Nations 2002). This is because, on average, the age of the respondent is likely to be close to that of her (or his) siblings. Thus, the proportion of a respondent's siblings alive is a good estimator for survival to the age of the respondent.

The method is based on the following assumptions: that all the siblings that fall in the sample are interviewed; that mortality does not vary by sibship size; that there is no correlation between the mortality experienced by siblings or that it is minimal; and that

the age pattern of mortality for the population under investigation can be explained by model life tables (United Nations 2002).

If siblings of a respondent aged x were, on average, also born x years ago, the proportion surviving among these siblings should approximate the probability of surviving to age x , l_x/l_0 (United Nations 2002). By collecting data from only those individuals of at least age 15 years, the method uses this argument to estimate the proportion of siblings surviving among those who had already survived to age 15 which is given by l_x/l_{15} .

The probability of surviving for respondents who have reached aged 15, is then related to

$$l_x/l_{15} = a(x) + b(x)S(x-5,5)$$

where $a(x)$ and $b(x)$ are coefficients and $S(x-5,5)$ is the proportion of brothers (or sisters) of respondents aged $x-5$ to x who are still alive having reached age 15. If the change in mortality has been approximately linear over time, the time location of sibling survival estimates, $t(x)$, is given by $t(x) = c(x) - d(x) \ln(S(x-5,5))$

where $c(x)$ and $d(x)$ are coefficients and $S(x-5,5)$ is the proportion of brothers (or sisters) who are still alive having reached age 15 among those reported by respondents aged $x-5$ to x . However, the method can give biased results if mortality varies by size of the family (Gakidou and King 2006). The method proposed by Gakidou and King (2006) seeks to address a key assumption of the sibling survivorship and other related methods. The assumption underlying the use of the sibling survivorship method is that mortality does not vary with the size of the family. If the assumption is violated (i.e. mortality varies with sibship size) Gakidou and King (2006) notes that mortality rates derived from the sibling survivorship may be biased downwards.

2.2.6.1 Direct Sibling Survivorship Method (Sibling History Method)

The direct sibling survivorship method, developed by Rutenberg and Sullivan (1991), is analogous to the direct method of estimating child mortality in that mortality rates are obtained by dividing the number of female (or male) deaths by person-years of exposure (Rutenberg and Sullivan 1991). The method uses information on respondents' siblings dates of birth and dates of death to give an estimate of adult mortality (Stanton, Abderrahim and Hill 2000).

The method assumes that: there is no relationship between number of siblings and their survival, mortality risks between siblings are not correlated and the data are of good quality (i.e. ages of respondents, siblings' ages at death, and years since death are reported accurately).

This method is described in detail by Rutstein and Rojas (2006). The method requires sibling vital status data 0-7, 7-14, and 0-14 years prior to the interview by five-year age group. The procedure involves calculating the proportion of dead siblings in each of the five-year age groups, then aggregating the estimates for each age group.

The method has its strengths and weaknesses. Its strengths are that it requires fewer assumptions than the indirect method; it allows for the calculation of period rates; it allows the monitoring of trends; and it permits data quality and plausibility checks that are not possible with the indirect approach. The weaknesses are that it is sensitive to data errors and also requires information on each sibling and complex data processing.

2.3 Levels and trends of mortality 1980-2005

Data available for the study of mortality in sub-Saharan Africa, including Zimbabwe, have improved over the past decades. This is largely attributable to the availability of large scale household surveys as well as demographic surveillance sites (The World Bank 2006). In the period under review, three national censuses were conducted, in the years 1982, 1992 and 2002, two intercensal demographic surveys, in 1987 and 1997, and four Demographic and Health Surveys (DHS), in the years 1988, 1994, 1999 and 2005. Both direct and indirect estimates of mortality can be derived using some of these data. Comparison of results obtained by applying these methods can be a useful tool in identifying completeness of death reporting as well as potential errors in the data. This section gives an overview of levels and trends of both child and adult mortality rates in Zimbabwe from 1980 to 2005.

2.3.1 Existing research on levels and trends in child mortality

Existing literature on levels and trends of child mortality in Zimbabwe can be classified according to two main groups: literature based on direct estimates and that based on estimates derived by the United Nations and other world bodies.

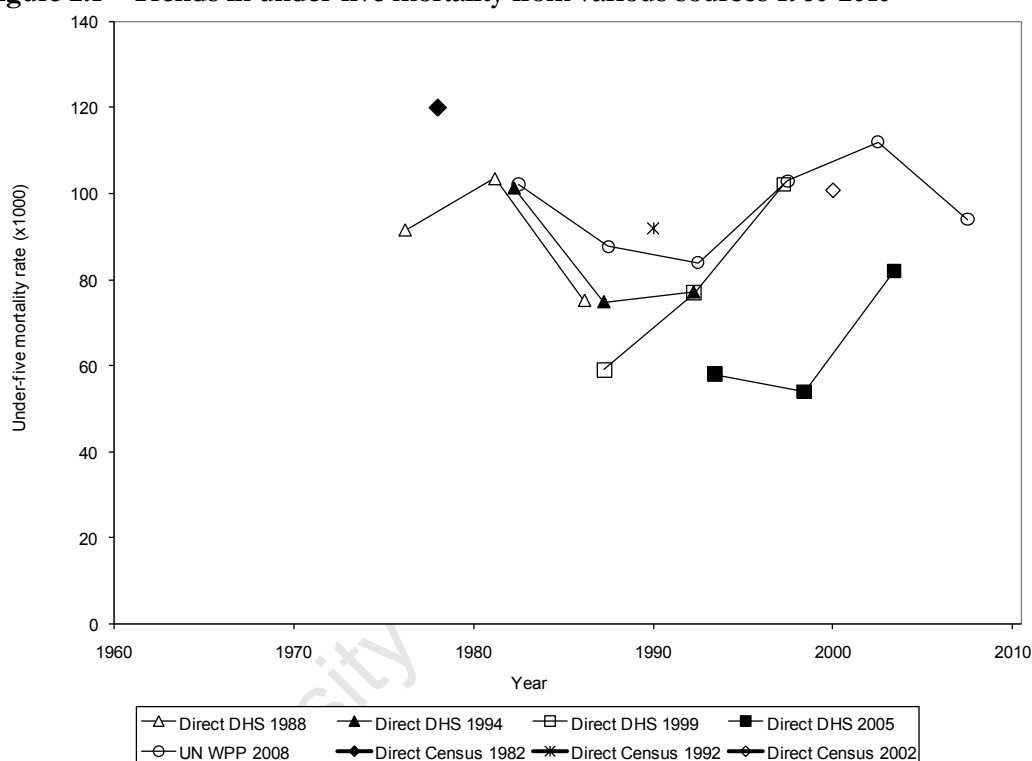
Direct estimates, based on full birth histories, are available from the censuses and household surveys conducted in the period 1980 and 2005. These estimates are the official estimates for child mortality in Zimbabwe. Figure 2.1 shows the time trend of under-five mortality using data from a variety of sources. The direct estimates from the DHS surveys suggest a gradual decline in the combined under-five mortality from about

109 deaths per 1000 live births in 1980 to about 75 deaths per 1000 live births in 1988, followed by a period of increasing infant mortality to about 100 deaths per 1000 live births in 1999 and a decline in the post 2000 period to 90 deaths per 1000 live births. Infant mortality rates follow a similar trend. The plot also depicts the direct estimates derived from the three censuses conducted in the period under review. The 1982 census suggests an under-five mortality rate of around 120 deaths per 1000 live births. The 1992 census suggests an under-five mortality rate of 92 deaths per 1000 live births, which represents a decline from the previous census. The under-five mortality rate from the 2002 census of 101 deaths per 1000 live deaths shows a rise from the previous census. Overall, the rates from the censuses are higher than those from the DHS.

The other source of child mortality estimates is the United Nations Population Division (UNPD). UNPD uses two approaches to produce estimates and projections. These approaches differ depending on the adult HIV prevalence. The first approach is used in countries with adult HIV prevalence of less than one percent. Mortality is estimated by models allowing for gains in life expectancy. The second approach is used for countries with adult HIV prevalence of at least one per cent. This is the approach applicable to Zimbabwe. The method, which is multi-staged, treats country mortality as a multiple decrement process. Mortality from non-HIV/AIDS causes (background mortality) and that from HIV/AIDS causes are treated separately as inputs into demographic and projection model. Background mortality for Zimbabwe is estimated using the North model life tables (United Nations 2009). HIV/AIDS mortality is added to the background mortality as an additional cause, through the Epidemic and Projection Package model and demographic model (DemProj), to come up with all-cause mortality (Stover, Johnson, Zaba *et al.* 2008; United Nations 2009). The resulting mortality rates can be adjusted based on past estimates from various sources (Reniers, Masquelier and Gerland 2010). The approach, thus, is not entirely independent of the empirical estimates as it takes into account the levels of mortality as suggested by both direct and indirect methods. The method suggests an under-five mortality rate of 102 deaths per 1000 live births for the year 1983, dropping to about 88 deaths per 1000 live births in 1988 before rising again to almost the level of the early 1980s (103 deaths per 1000 live births) in 1998 and eventually to a high of 112 deaths per 100 live births in 2003. This is followed by a decline in under-five mortality in the late 2000s. These estimates are, on average, higher than the DHS direct estimates. They are, however, lower than those from the 1982 and 1992 censuses.

The figure also highlights potential problems with the data. For example, the DHS 2005-6 suggests an inconsistent trend as the under-five mortality rate for the time period 1998 (52 deaths per 1000 live births does not agree with the previous DHS 1999 under-five mortality rate of 102 deaths per 1000 live births in 1999)(Central Statistical Office (CSO) [Zimbabwe] and Macro International Inc. 2007:111). The estimates from DHS 2005 appear too low.

Figure 2.1 Trends in under-five mortality from various sources 1960-2010



Other researchers have conducted detailed statistical analyses on the DHS using direct estimates. Marindo and Hill (1997) used the DHSs in 1988 and 1994 to describe the levels and trends in child mortality nationally as well as regionally. In addition, they fitted a logistic regression model in order to explain factors associated with the decline (particularly education and fertility). Their research found that child mortality rates started declining from 1980 to around 1988 after which they levelled off or even increased. The analysis also concluded that mother's education was associated with reduced infant mortality while multiple births and high parity births with short birth intervals were associated with high infant mortality. The study by Kembo and Van Ginneken (2009) used a Cox proportional hazards model to determine the impact of maternal, socioeconomic and sanitation variables on infant and child mortality in Zimbabwe using DHS 2005-6 data. The analysis concurs with work by Marindo and Hill

(1997) that high birth orders with a short preceding interval had a high risk of infant mortality and that multiple births are associated with increased infant mortality. However, the work also suggested that mother's education did not impact on infant mortality. The finding is not consistent with analyses from previous DHS surveys which suggest reduced risk of infant deaths for children born from mother's with some level of education.

Marindo and Hill (1997:1) note that there was more general agreement in child mortality estimates than there was on fertility. Perhaps, this partly explains the dearth of substantial peer-reviewed research using indirect methods of child mortality in Zimbabwe. The few publications that do exist are for small area analyses. For example, a paper by the Manicaland Study group, used an empirical and mathematical model to determine the extent of correlation between mothers and children's AIDS mortality (Gregson, Hallett, Kurwa et al. 2009). Their findings suggest that there is a need to correct for the possible violation of the assumption of insignificant correlation between mothers and their children's mortality in generalised HIV areas. The finding is, nevertheless, critical for indirect estimation techniques such as Brass CEB/CS method. This means that in its usual form (i.e. without an adjustment for the impact of HIV) the Brass CEB/CS method can not be used to estimate recent child mortality in Zimbabwe.

Overall, the direct estimates have been the cornerstone of the estimation of child mortality in Zimbabwe though the most recent DHS survey suggests that it may be necessary to use indirect approaches to complement them.

2.3.2 Existing research on levels and trends of adult mortality

Various researchers have attempted to assess the levels and trends of adult mortality in Zimbabwe to date. They include:

- The impact of HIV/AIDS on Adult Mortality in Zimbabwe (Feeney 2001)
- Assessing adult mortality in HIV-1-afflicted Zimbabwe (Lopman, Barnabas, Hallett *et al.* 2006)
- Adult mortality in Sub-Saharan Africa: Evidence from Demographic and Health Surveys (Timæus and Jasseh 2004)
- Adult mortality in Southern Africa using deaths reported by households: Some methodological issues and results (Dorrington, Timæus and Gregson 2006).

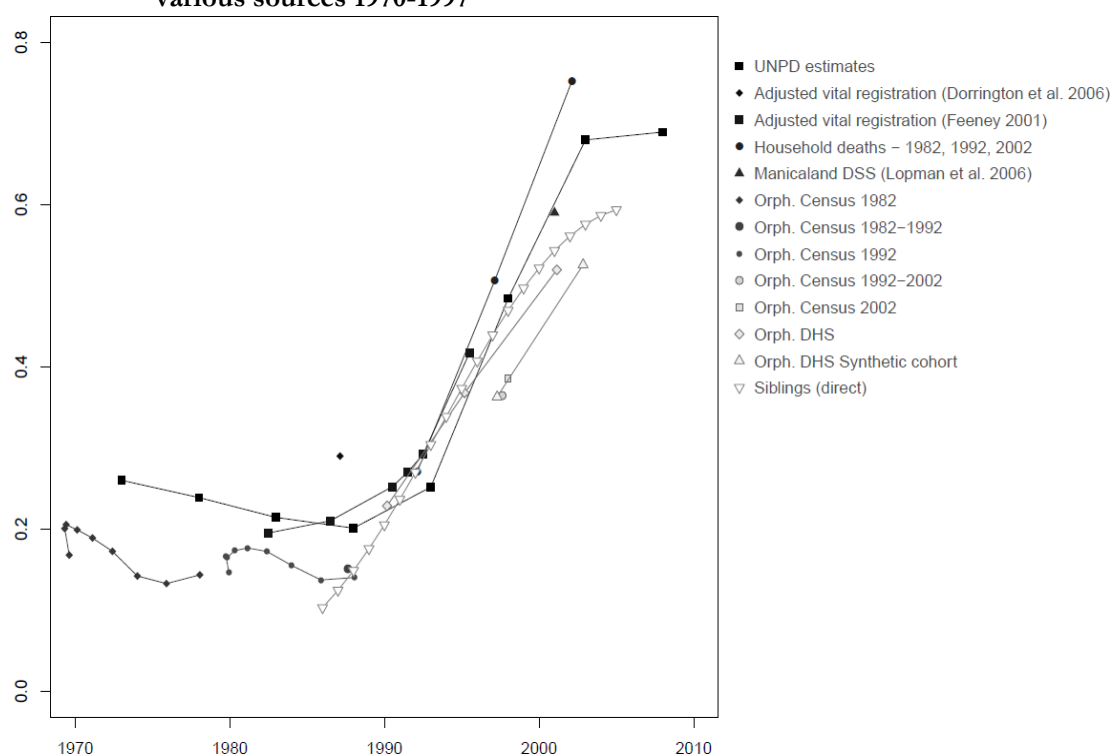
In contrast to child mortality, most of the research on adult mortality uses indirect methods. Overall, the research shows increasing adult mortality in the recent time and

also suggests that HIV/AIDS might be responsible for the rise. The work by Feeney (2001) represents the first major attempt to get insight into the adult mortality level and trends in post-independent Zimbabwe. He applied a series of indirect techniques to derive estimates of the probabilities of dying for ages up to at most age 65 years in the period 1982 to 1997. His work suggests that Zimbabwe experienced a sharp increase in adult mortality over the period from mid-1980s to mid-1990s. The probabilities of dying before age 60 for those alive at 15 years for females rose by over 100 per cent from 0.2 in 1982 to over 0.5 in 1997. In addition, Feeney (2001) speculates that the increase in mortality was due to HIV. A shortcoming of the research by Feeney is that it uses methods that are particularly sensitive to low completeness of death registration. Levels of completeness below 60% are likely to result in a great deal of uncertainty around the estimates, and completeness of vital registration was significantly below 60%.

Estimates of adult mortality in Zimbabwe produced by various researchers support the hypothesis that adult mortality rose rapidly from the mid-1980s to the late 1990s but they differ as far as the mortality level is concerned. For example, research by Timæus and Jasseh (2004) on estimating adult mortality using sibling histories data from 23 sub-Saharan countries yield estimates of $_{45}q_{15}$ for Zimbabwe that are 10 per cent lower in 1997 than Feeney's estimates for the same period and 30 per cent lower in 1990 than the estimates derived by Feeney (2001) for the year 1990. Analysis of data suggests that the sibling survival method under-estimates the levels of adult mortality in periods more distant in the past from the survey and hence exaggerates the slope of the increase in the late 1980s and early 1990s UNAIDS (2005).

Figure 2.2 illustrates the probabilities of dying before age 60 for those alive at 15 years for females produced by various researchers (Reniers, Masquelier and Gerland 2010:31). The plot shows rising mortality risks for women in Zimbabwe in the period 1985 to about 2005.

Figure 2.2 Probability of a female aged 15 dying before age 60 years: Estimates from various sources 1970-1997



Source: (Reniers, Masquelier and Gerland 2010:31)

Furthermore, Dorrington, Timæus and Gregson (2006) used a combination of the generalized growth balance and synthetic extinct generations methods to assess potential biases from census death data and produce estimates of mortality. They found that estimates of adult mortality based on household deaths were consistent with those from other sources in the trends but not the level. The results show a rapidly increasing trend in adult mortality from about 1990 onwards. The estimates are also more consistent with those produced by Timæus and Jasseh (2004) than those from Feeney (2001). Their estimates suggest that it is likely that Feeney's estimates may overestimate adult mortality. Research from a Manicaland study suggest that mortality had begun to rise by 1993 (Gregson, Anderson, Ndlovu et al. 1997).

An important area of research in adult mortality estimation has been on the impact of HIV on mortality. Lopman and Gregson (2008) used death data from two Zimbabwean cities in an attempt to reconstruct HIV incidence. The study suggests a peak HIV incidence of between 3 and 6 per cent, occurring between 1988 and 1990. However, this would not explain the rapid rise in mortality witnessed in these early years of the epidemic. Since AIDS mortality lags incidence by about nine years in adults, the incidence will have been associated with mortality occurring in the mid to late 1990s.

2.4 Conclusions

Indirect demographic methods can still be used to estimate both child and adult mortality provided that assumptions underlying their use are not violated. This is important in a country like Zimbabwe that is severely affected by the HIV/AIDS epidemic. HIV/AIDS violates the most important assumption underlying the use of some of the methods. The assumption that the mother's mortality is independent of the child's mortality is violated in countries with generalised epidemics because of vertical transmission of HIV from mother to child.

The DHS direct method has been the mainstay of estimating child mortality. This might be so because the method does not depend on model life tables to translate death rates into a common probability and has, until recently been assumed to suffer minimally from the impact of the HIV/AIDS epidemic (Hallett, Gregson, Kurwa *et al.* 2010). Very little attention has been paid to indirect methods on estimating child mortality, except maybe by the United Nations Population Division. Indirect methods, on the other hand, have been the most used to estimate adult mortality with the exception of the direct sibling survivorship method popularized by the DHS surveys.

Overall, it is clear from the literature review that various researchers have produced estimates of mortality at various time periods. There is broad consensus on the trends of both child and adult mortality. However, there is variability as far as the level is concerned. What is also clear is that some of the research was conducted in the period when less was known about the epidemiology of HIV/AIDS. As such, some of the earlier work might need to be reworked to produce more robust estimates. Whilst Zimbabwe is not short of research in mortality estimation, there has not been a systematic approach to deriving the level and trends of both child and adult mortality using most of the data that exist now. This is the gap this research intends to fill by deriving estimates that are robust and trends over a fairly long period. The period after 2005 is not included in this research because it represents a period of heightened political tensions and estimates for this period may not result in a robust trends or levels of mortality.

3 CHILD MORTALITY ESTIMATION

3.1 Introduction

This chapter is in two parts. The first part deals with the data, the direct method and the estimates produced from the method. The second part looks at indirect estimation procedures and results produced by applying them. Two known measures of childhood mortality (infant mortality and under-five mortality) are derived using direct and indirect methods. These are then compared to the United Nations Population Division (UNDP) projections and conclusions drawn from the analyses.

3.2 Data sources

A number of data sources are available to assess the levels and trends of child mortality in Zimbabwe for the period 1980 to 2005. These include the three post-independence censuses carried out in 1982, 1992 and 2002; and the 1988, 1994, 1999 and 2005 Zimbabwe Demographic and Health Surveys (ZDHS). All these data sets included questions that can be used for the direct or indirect estimation of child mortality. The questions form part of the full birth histories collected in all these surveys. In addition, data on total children ever born and children dead can be easily derived from each of the censuses and surveys.

3.3 Direct estimates

Child mortality rates derived from Demographic and Health Surveys are often the only credible source of mortality estimates in countries with poor data. These rates are obtained from full birth histories and provide data that are not normally affected by some of the challenges of indirect method (for example finding a suitable life table). In this research, data from all of the four DHSs conducted in the review period contain information from which rates can be estimated directly. These rates are published in DHS reports. The accuracy of the DHS estimates was verified by using the primary data files and reproducing what was published.

Table 3.1 shows, by sex, the estimated levels and trends of neonatal, post neonatal, infant, child and under-five mortality as reproduced from the 1998, 1994, 1999 and 2005 surveys. The derived rates match those produced by Macro International and refer to the period 0-9 years before the survey.

Table 3.1 Direct child mortality rates in Zimbabwe, DHS 1988-2005

Rates	DHS 1988		DHS 1994		DHS 1999		DHS 2005	
	Male	Female	Male	Female	Male	Female	Male	Female
Neonatal mortality	34.9	25.6	27.5	22.4	28.3	24.1	23.2	19.2
Postneonatal mortality	28.3	23.9	29.4	23.1	34.8	32.2	27.6	28.6
Infant mortality	63.2	49.5	56.9	45.5	63.1	56.2	50.8	47.8
Child mortality	29.2	30.8	26.4	25.6	34.5	30.5	21.2	20.8
Under-five mortality	90.6	78.8	81.8	69.9	95.4	85.0	71.0	67.6

Figure 3.1 below shows a plot of period rates of under-five mortality. These mortality rates refer to periods 0-4 years, 5-9 years and 10-14 years before the survey. The plot suggests declining child mortality from 1980 to the mid-1980s, followed by rising mortality after 1985. Direct estimates of the rates of child mortality from the 2005 DHS survey appears to produce mortality that is too low and even contradicts the previous, DHS 1999, survey. Although the reason for this is not obvious it might be due to the sampling bias in the DHS 2005 associated with rapid out migration from Zimbabwe due to the economic decline at the time of the survey.

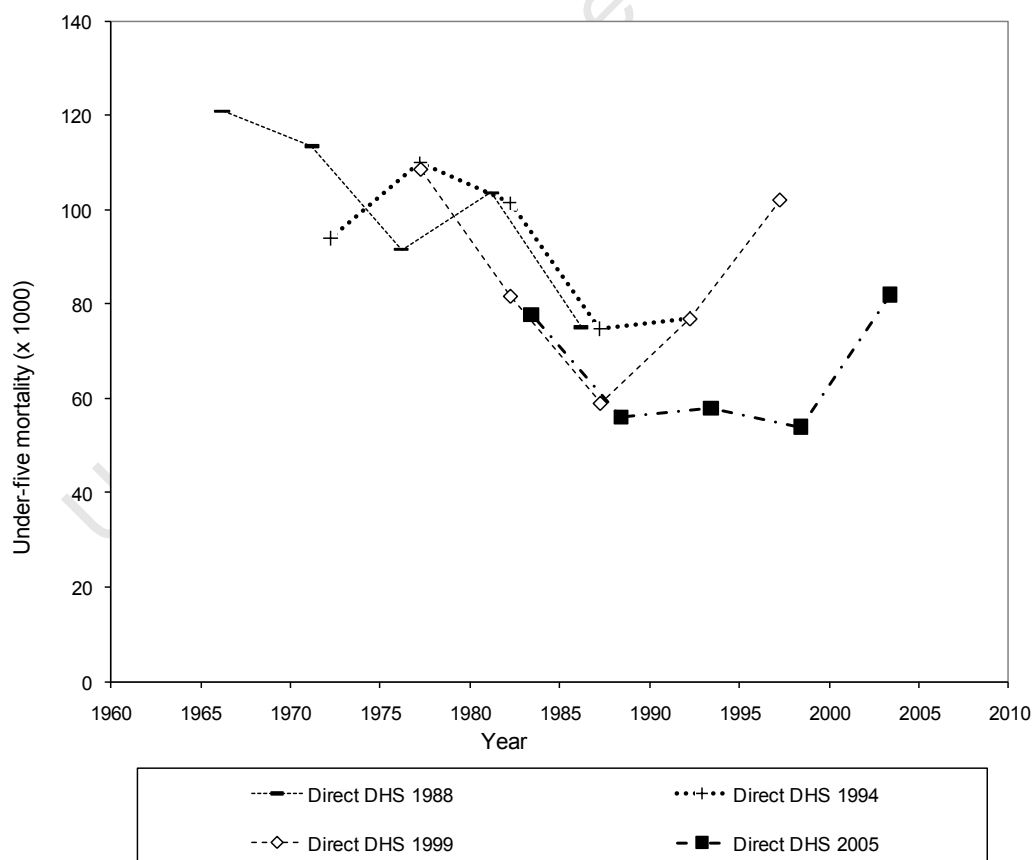
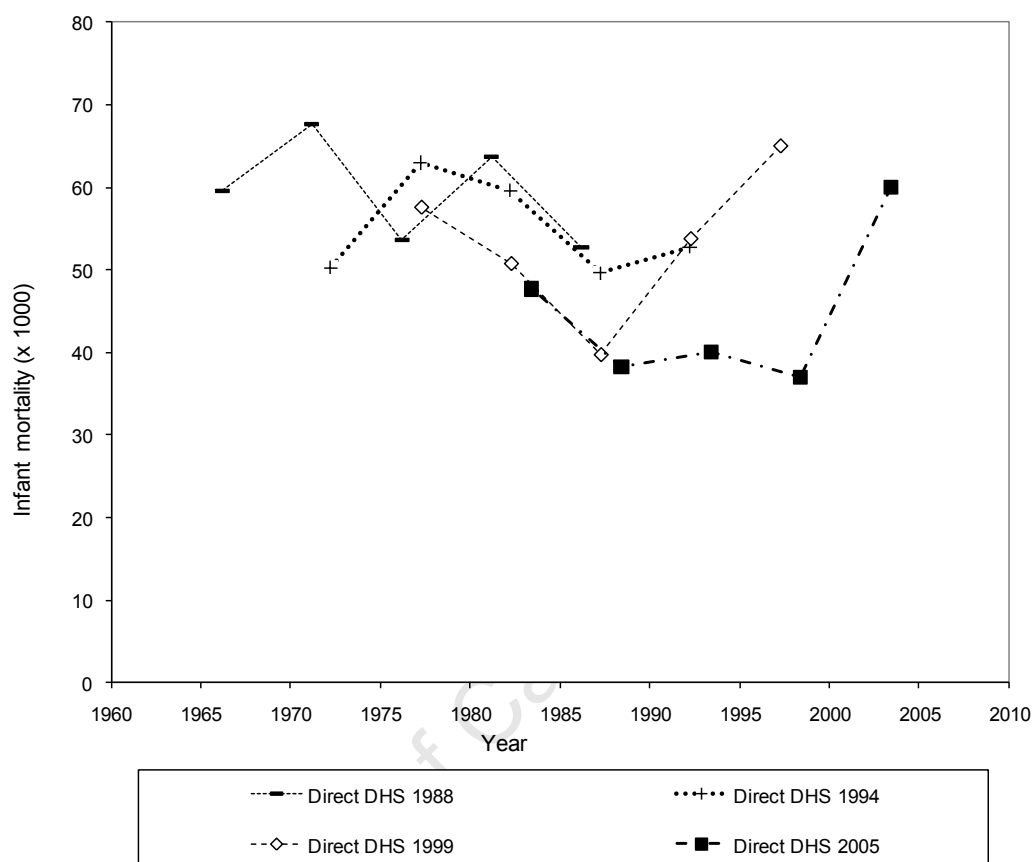
Figure 3.1 Direct under-five mortality in Zimbabwe: 1980-2005

Figure 3.1 shows that under-five mortality was very high in 1980 (over 100 children dying per 1000 live births) and that mortality started to decline to the mid-1980s and, based on results from the 1999 DHS, increased to levels similar to those in the early 1980s. A similar trend is also apparent on the infant mortality in Figure 3.2. The

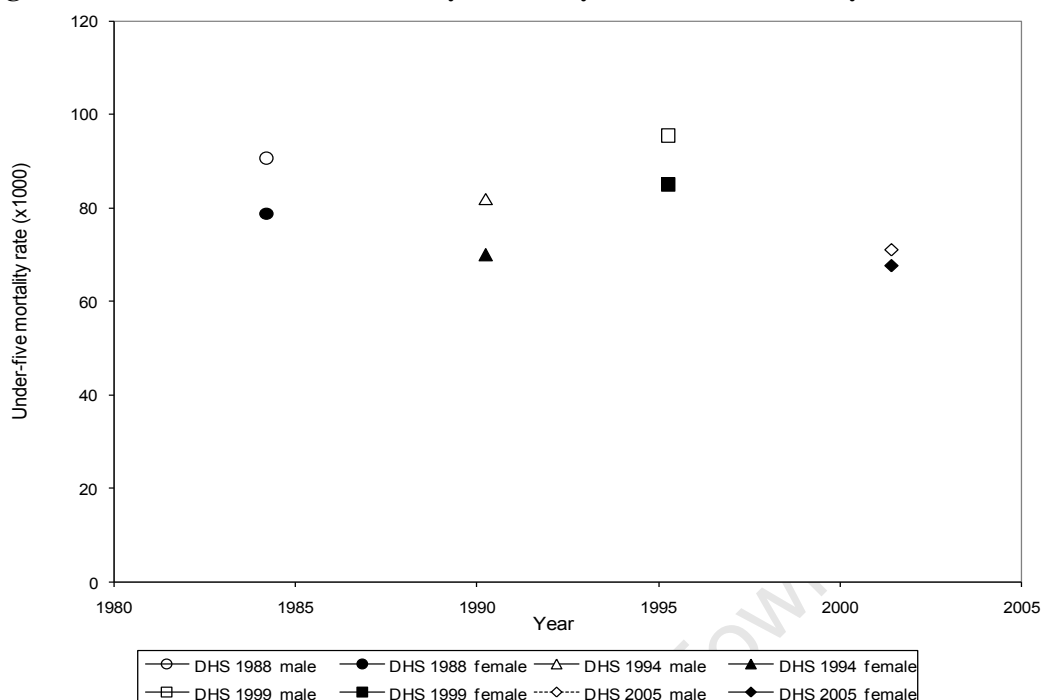
mortality rates for the period farthest away from the survey date appear to be unreliable and are more likely to be affected by sample size as well as recall bias.

Figure 3.2 Direct infant mortality rates in Zimbabwe: 1980-2005



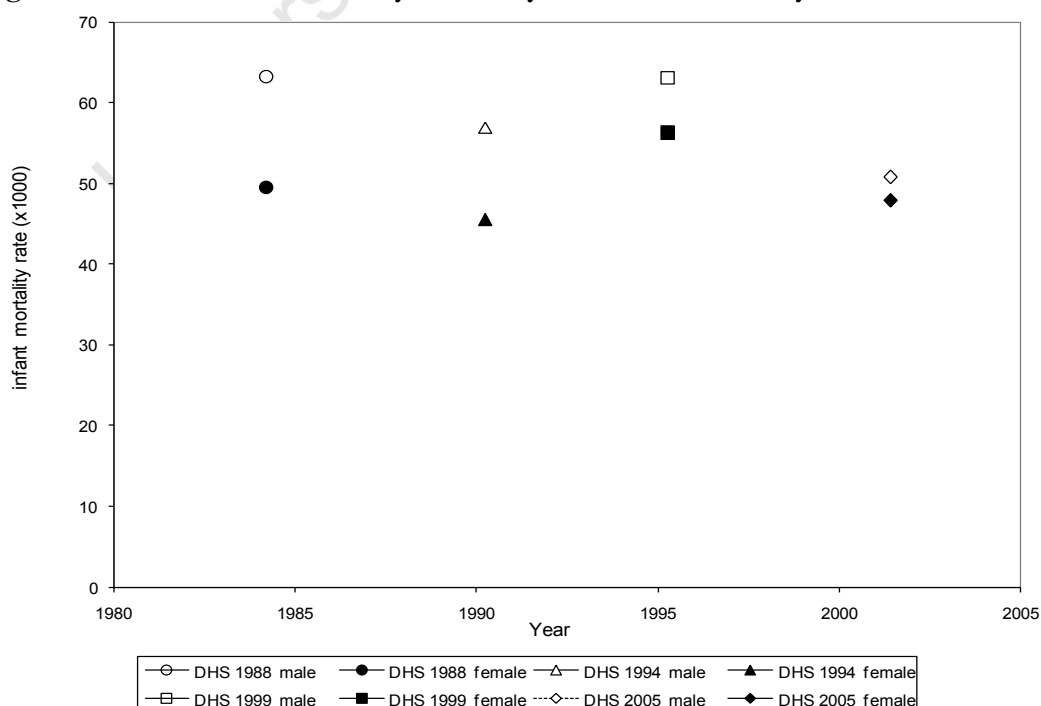
Infant and under-five mortality rates are also plotted, by sex, for the period 0-9 years before the survey. Figures 3.3 and 3.4 shows the trends of mortality for boys and girls in the period 1980 to 2005. Under-five mortality for boys dropped from about 90 deaths (per 1000 lived births) in 1984 to just over 80 deaths (per 1000 live births) in 1990 and then rose again to near 100 deaths (per 1000 live births) in 1995 followed by a decline in 2002. The path for girls is similar to that of boys. As can be expected, mortality for girls is lower than that of boys. It is worth noting that mortality for girls appear much closer to that of boys in the 2005 DHS.

Figure 3.3 Direct under-five mortality rates 0-9 years before the survey: 1980-2005



The trends for infant mortality for both boys and girls resembles the under-five mortality trends. However, it appears though, in the earlier years, that the mortality for boys was much higher than that of girls. In the early 1980s, infant mortality rates for boys and girls were 63 and 50 deaths per 1000 live births respectively and in 2002, the infant mortality rates were 51 and 49 deaths per 1000 live births respectively.

Figure 3.4 Direct infant mortality rates 0-9 years before the survey: 1980-2005



3.4 Indirect estimates

This section presents results from applying the Brass CEB/CS method (and a variant of the Ward and Zaba (2008) correction that allows adjustment for non-stable HIV/AIDS epidemic) to the three post independence censuses as well as the four DHS surveys conducted in Zimbabwe to date. The full mechanics of the method is described in an earlier chapter.

In a nutshell, the original Brass CEB/CS method converts the proportion of children dead by the age of their mother into probabilities of dying before reaching age x and time point to which the estimates refer. These probabilities can then be converted into common indices such as infant mortality and under-five mortality rates by using model life tables. As mentioned in the literature review, the CEB/CS method in its original form may not be accurate in countries that are affected by the severely affected by HIV/AIDS epidemic. This research uses a modified version of CEB/CS which adjusts for HIV/AIDS related bias. The key difference between the original method and Ward-Zaba approach is that after calculating the probabilities of dying before reaching x and the time reference, the Ward-Zaba method allows one to estimate the bias and adjust the probabilities of dying for the bias. The bias is a function of HIV/AIDS prevalence in women of child-bearing age. Ward and Zaba (2008) propose two methods to estimate the bias; the basic method and the extended method. The difference between the two methods is that extended method is a three parameter method in that it adds a component of HIV/AIDS prevalence of women aged 15-19 to the basic equation. They also give multipliers that are needed to estimate the bias for each of the methods. For this research, the basic method is used to adjust for HIV/AIDS bias.

After adjusting for the bias, one derives common indices in exactly the same way as the original method except that one may need a life table incorporating HIV mortality. The Brass logit system with $\beta = 1$ was used to convert survivorship probabilities into common mortality indices such as infant and under-five mortality. The Brass General Standard was used as the model life table. This model life table is normally used where there is difficulty in finding a suitable model life table. The ideal option would have been to derive a life tables using data provided for by UNPD as that would have given life table that is specific to Zimbabwe, but time prevented this being done. Below is a presentation of the results.

Tables 3.2 and 3.3 show under-five mortality rates for both sexes derived using the censuses and DHS surveys respectively. Estimates from the censuses suggest an initially high child mortality (159 deaths per 1000 live deaths) which then went down to

92 deaths (per 1000 live births) by 1988 and then rose again to 138 deaths (per 1000 live births) in 2001.

Table 3.2 Ward-Zaba estimates of under-five mortality for both sexes, Census

Year	Census 1982	Year	Census 1992	Year	Census 2002
1981.6	163	1991.5	133	2001.6	138
1980.6	133	1990.5	104	2000.5	114
1978.4	136	1988.5	92	1998.2	109
1976.0	143	1986.4	95	1995.8	118
1973.4	147	1984.2	99	1993.1	106
1970.7	154	1981.6	111	1990.4	108
1967.7	159	1978.7	115	1987.4	116

Estimates derived from the DHS surveys also concur with those from the census. They show a consistent pattern of child mortality characterised by a gradual decline of mortality from 1970s to around 1990 where the increases in child mortality became apparent.

Table 3.3 Ward-Zaba estimates of under-five mortality for both sexes, DHS

Year	DHS 1988	Year	DHS 1994	Year	DHS 1999	Year	DHS 2005
1987.9	133	1993.7	139	1998.7	155	2004.9	172
1986.9	91	1992.7	117	1997.6	127	2003.9	100
1984.8	99	1990.5	96	1995.4	124	2001.5	90
1982.6	85	1988.2	97	1993.0	111	1999.0	104
1980.1	95	1985.7	92	1990.4	91	1996.3	97
1977.4	96	1983.0	93	1987.7	94	1993.5	110
1974.4	102	1980.1	96	1984.8	102	1990.6	130

Figure 3.5 shows a consistent pattern of indirect male infant mortality estimates characterised by a decline of mortality from over 100 deaths (per 1000 live births) in 1960s to around 60 deaths (per 100 live births) in 1988, after which the increases in child mortality became apparent. The plot also shows signs that male child mortality may have begun coming down after the year 2000. Male child mortality rates derived from the 1982 census appear to be too high if compared to estimates derived from the other censuses and surveys. Infant mortality rates of the youngest women are generally higher than average. If the results from the youngest cohort (15-19 age group) are removed then the trends become clearer. Again the results based on the DHS 2005 are out of line. Unfortunately the reason for this was not investigated.

Figure 3.5 Indirect infant mortality rates, Males

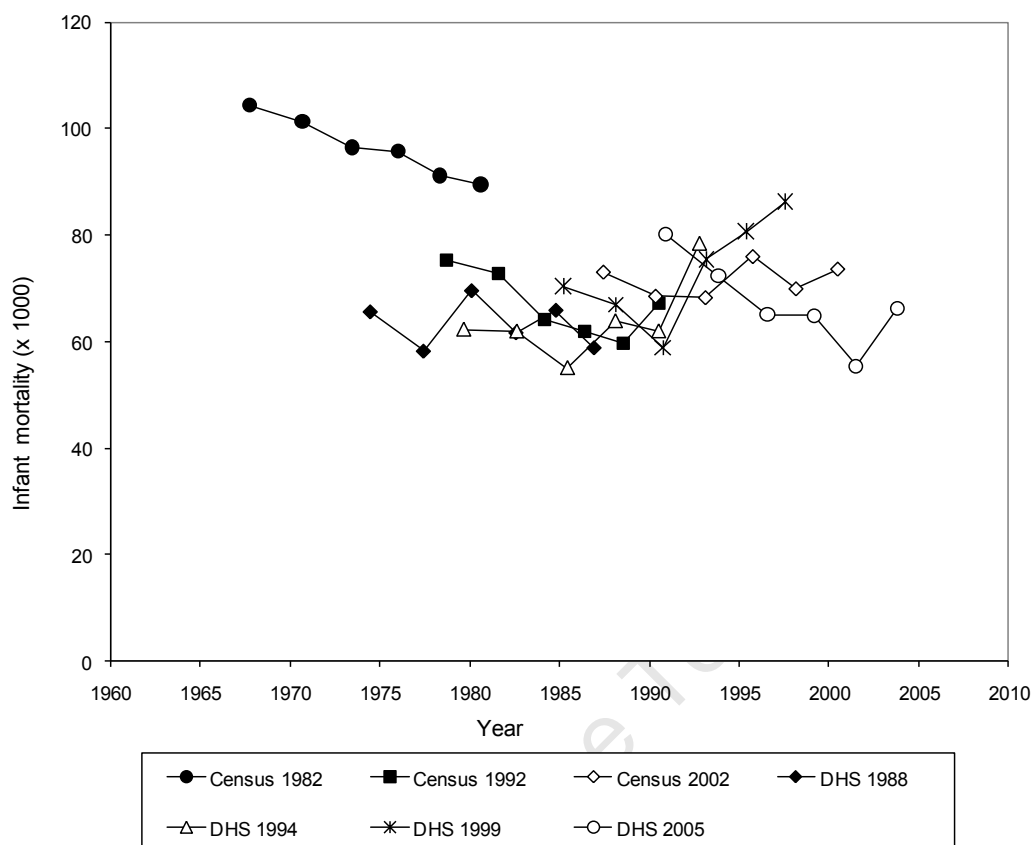
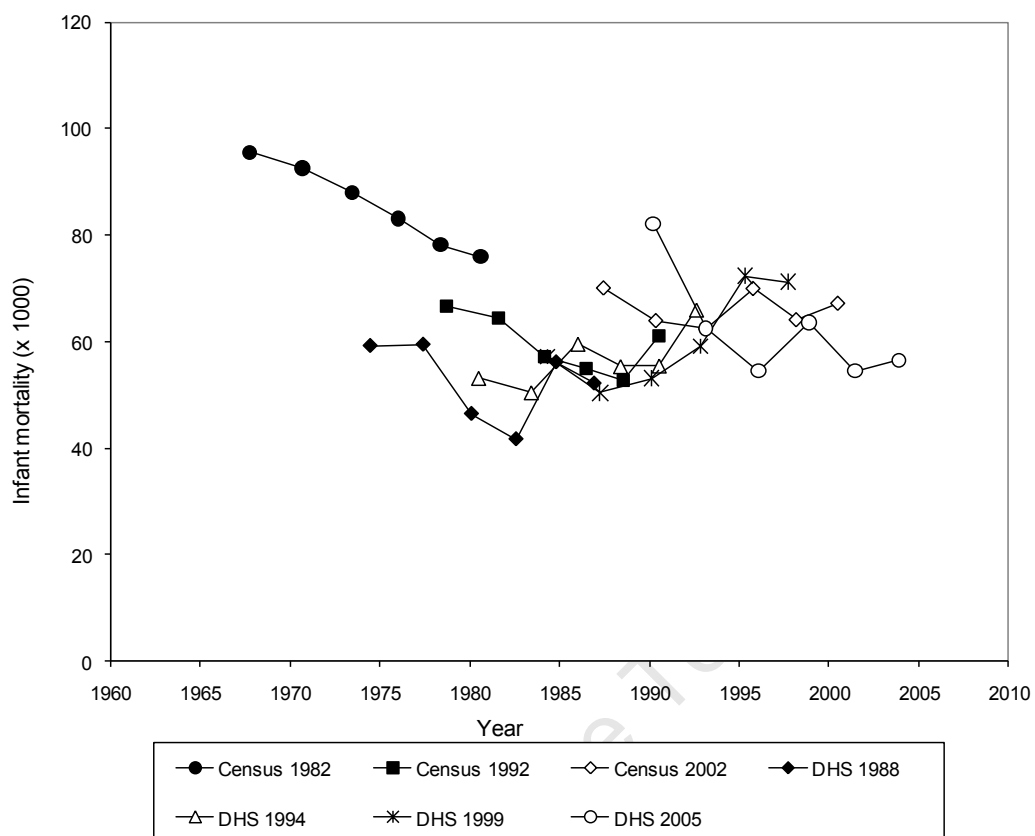


Figure 3.6 gives infant mortality rates for females. The trend is similar to that of males. Again, female child mortality from reporting of the youngest women has been excluded. The plot suggests that female child mortality had been on a downward trend prior to 1980. It continued this trend until around 1985 when it started to rise to a high of about 71 deaths per 1000 live births around 1998 and then appear to have started to decline. However, estimates produced from censuses and surveys vary considerably.

Figure 3.6 Indirect infant mortality rates, Females



3.5 Comparison of child mortality estimates

In order to arrive at accurate estimates, the child mortality estimates derived from the direct method are compared to those from Ward-Zaba variant of the CEB/CS. Figures 3.7, 3.8 and 3.9 show the plot of the variety of estimates from the two methods. In addition, estimates derived by the UNPD are also plotted on the same graph. The data show remarkable consistency as far as the trends are concerned. However, estimates of the mortality of children of women aged 15-19 using the indirect method have been excluded from the plots, because these estimates are biased upward.

Figure 3.7 Under-five mortality rates from a variety of sources, both sexes

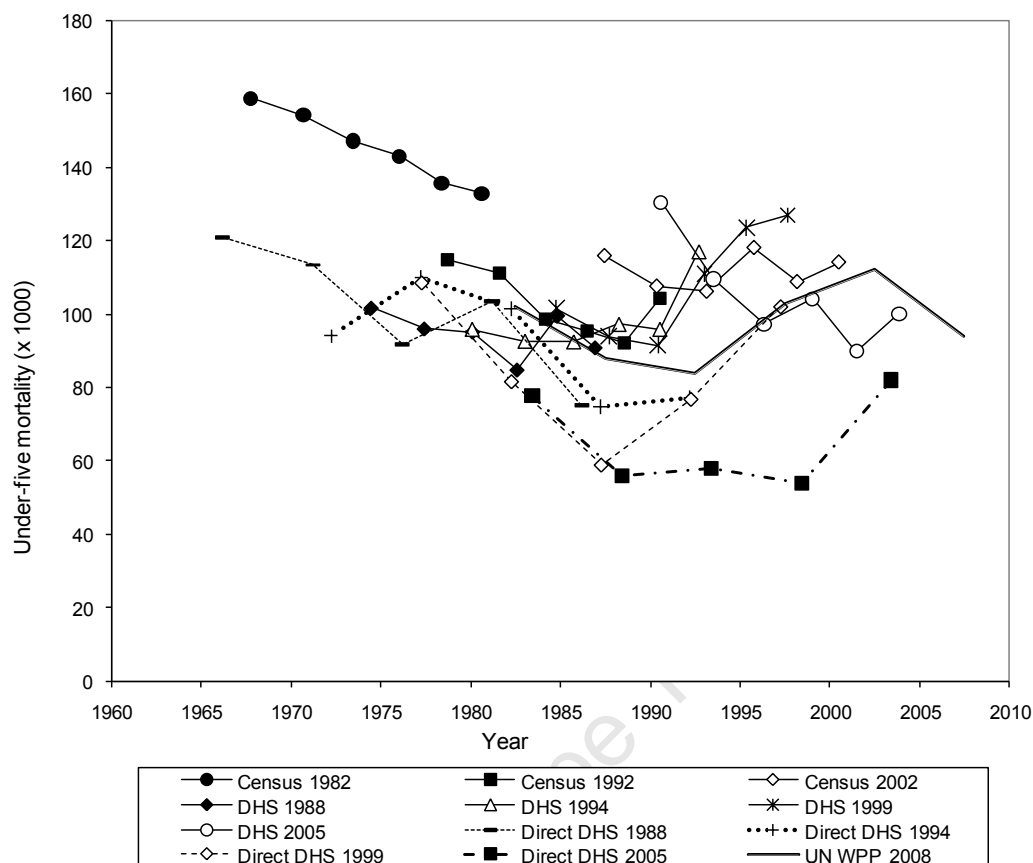
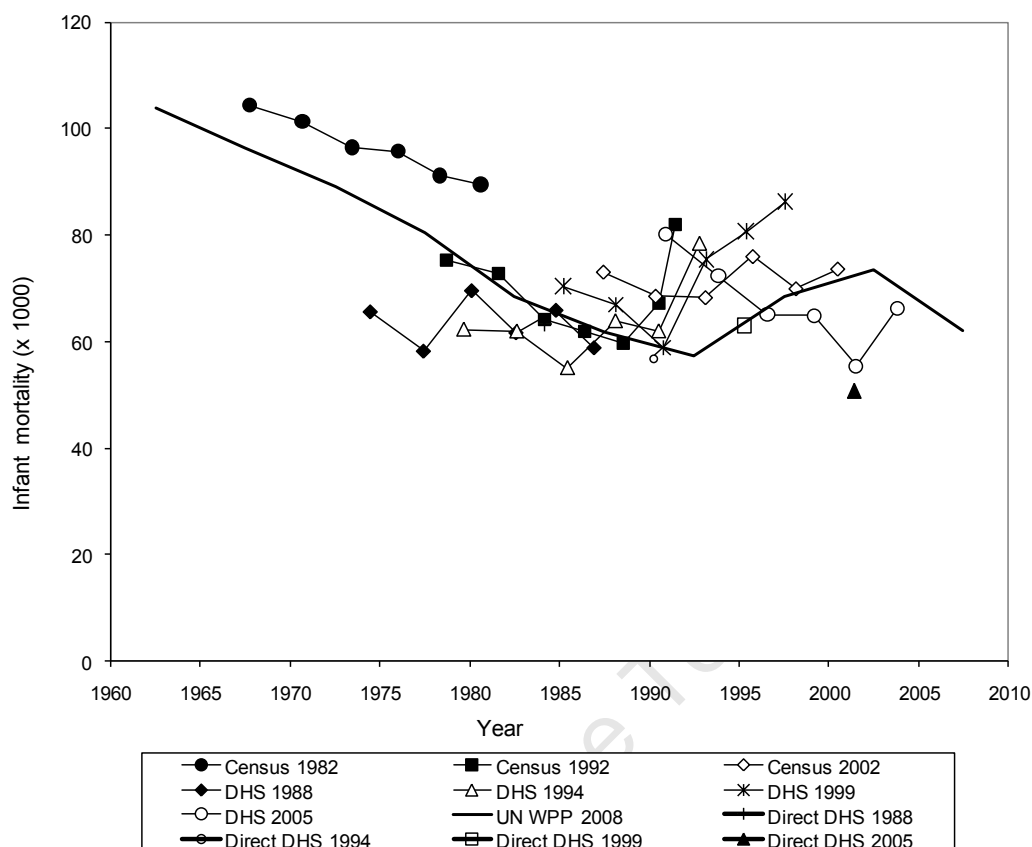


Figure 3.7 shows the plot of under-five mortality rates for both sexes combined. The indirect rates are all lower than the estimates from the UNPD. Estimates derived from the indirect methods are all higher than those of UNPD except those from the 2005 DHS. Analysis of other recent data sources, unavailable at the time of this research, is needed to understand the unusual mortality from the DHS 2005. The plot also highlights the problems in deciding on firm estimates of under-five mortality.

Figure 3.8 Infant mortality rates from a variety of sources, males



Compared to the UNPD estimates and projections, mortality rates after the year 1990 from the indirect method appear to be much higher. This is the case for both sexes. This may be due to the choice of the life table and (or) the adjustment for HIV/AIDS used in the calculation of these rates. This is in stark contrast to the estimates from the direct method which are close to UNPD estimates and projections except for the estimates based on the DHS 2005. Figure 3.8 suggests that male infant mortality peaked much earlier than is predicted by the UNPD. The estimates show that mortality peaked around the year 1997 before it began to fall while the UNPD estimates and projections shows the peak around the year 2002 before it started to come down. Female infant mortality shows a similar trend. The indirect methods of mortality are dependent on the right model life table being used. As a way of checking the effect of the life table on the results, a different life table is used to derive summary indices (see Figure 3.9).

Figure 3.9 Infant mortality rates from a variety of sources, females

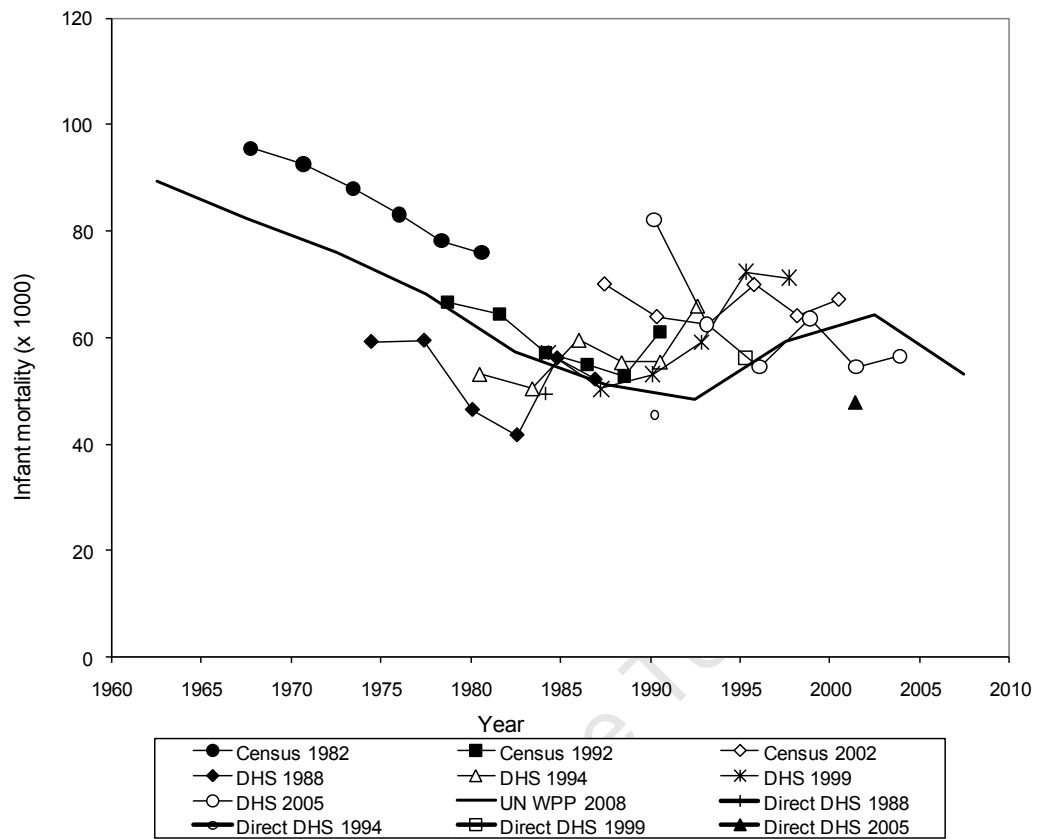
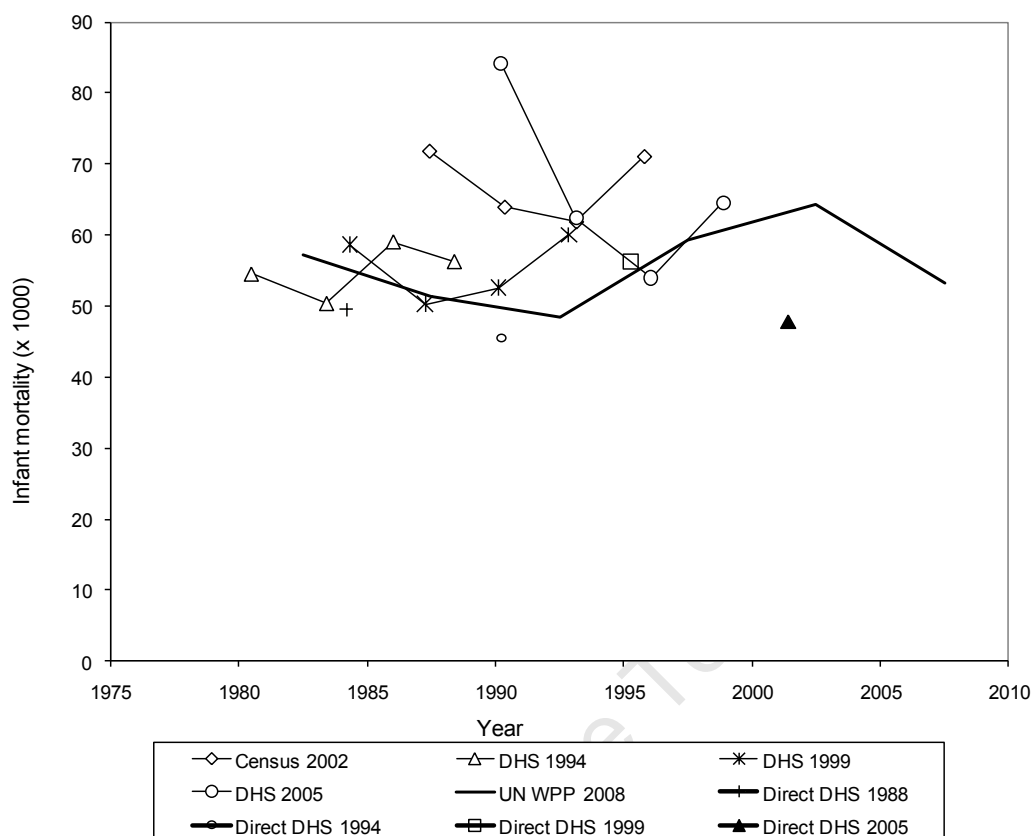


Figure 3.10 below shows the effect of using the INDEPTH model life table to derive indirect estimates of infant mortality in the period beginning 1990. A plot of the estimates suggests that using life tables other from the Brass General Standard (e.g. INDEPTH life tables) does not seem to have a material effect on the estimates. The plot does not show any particular trends.

Figure 3.10 Infant mortality rates derived using the INDEPTH model life table, females



3.6 Conclusions

Child mortality estimates in Zimbabwe suggest three trends in mortality in the period 1980 to 2005. The rates show that, indeed, child mortality was on a sustained downward trend from as far as the 1960s. This trend, however, changed in the mid- to late 1980s as child mortality began to rise. After the year 2000, child mortality appears to have started to come down again. While the trends have been consistent for both direct and indirect methods, the levels of child mortality have been variable between the two approaches. Certainly, both infant and under-five mortality estimates from the direct method are lower than those from the indirect method. A possible reason, among others, for the difference in these estimates might be bias.

Both methods are based on the assumption, among others, that a mother's mortality is not correlated to their child's mortality. The estimates based on the direct method are not adjusted for this bias. Work on estimating the bias in estimates using full birth history data has only recently been published (Hallett, Gregson, Kurwa *et al.* 2010). The adjustment by Ward and Zaba (2008) minimises this bias in the indirect Brass's CEB/CS method. However, the model life table that was used with the method does not include the age pattern of HIV/AIDS mortality. As a check, using a life table

incorporating the impact of HIV/AIDS did not produce any better estimates. The plots of all the child mortality rates show that deriving an estimate of the true level of mortality is a challenge.

4 ADULT MORTALITY ESTIMATION

4.1 Introduction

This section presents the results of applying the adult mortality techniques to censuses and surveys data. It begins with the estimates based on death distributions, and then goes onto estimates based on the survival of close relatives. It then compares all the derived estimates with those from the UN Population Division. Adult mortality is estimated by means of ${}_{45}q_{15}$ (i.e. the probability of dying before reaching age 60 years for someone alive at age 15 years), a common measure of adult mortality.

4.2 Estimates based on death distribution methods

Estimates of adult mortality are derived by using the General Growth Balance (GGB) on its own and the combined GGB and Synthetic Extinct Generations method (SEG) methods (i.e. the GGB is used to adjust for relative undercount of the censuses and the adjusted distributions are then used as input in the SEG).

4.2.1 Data and methods

The data used for the estimation of adult mortality from death distribution methods are primarily from the three post independence censuses (1982, 1992 and 2002) conducted in Zimbabwe. These data are in the form of the distribution of population by age and sex as well as the distribution of household deaths by age and sex. In addition, deaths from vital registration are also available for the period 1982 to 1992 but were not used for the analysis as they are too incomplete for use with the methods. Data on net migration are not readily available but are estimated.

Figure 4.1 Deaths reported by households: Females

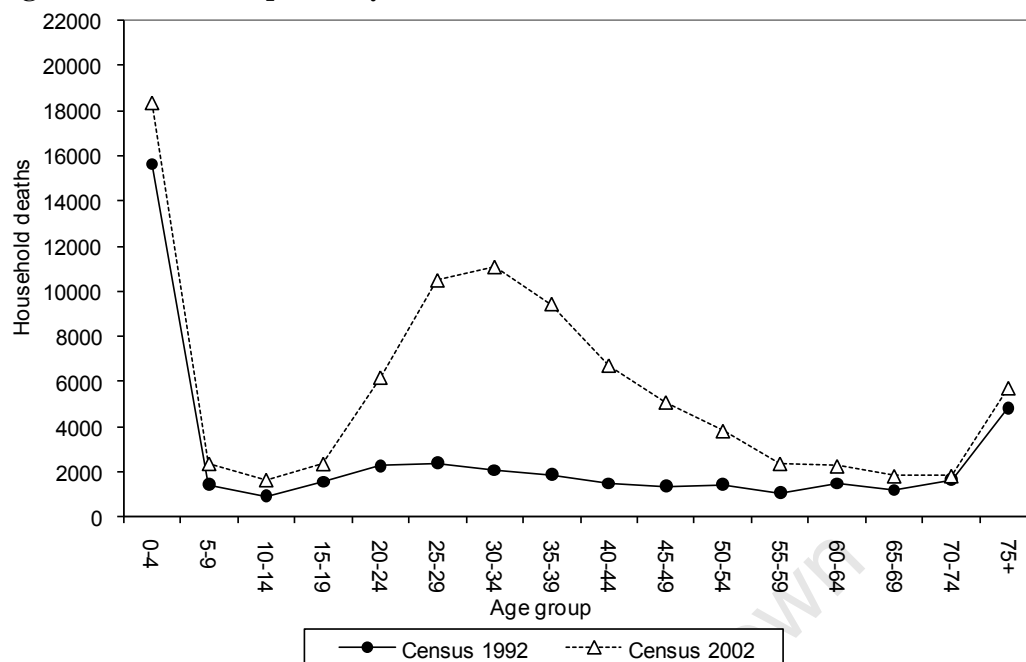
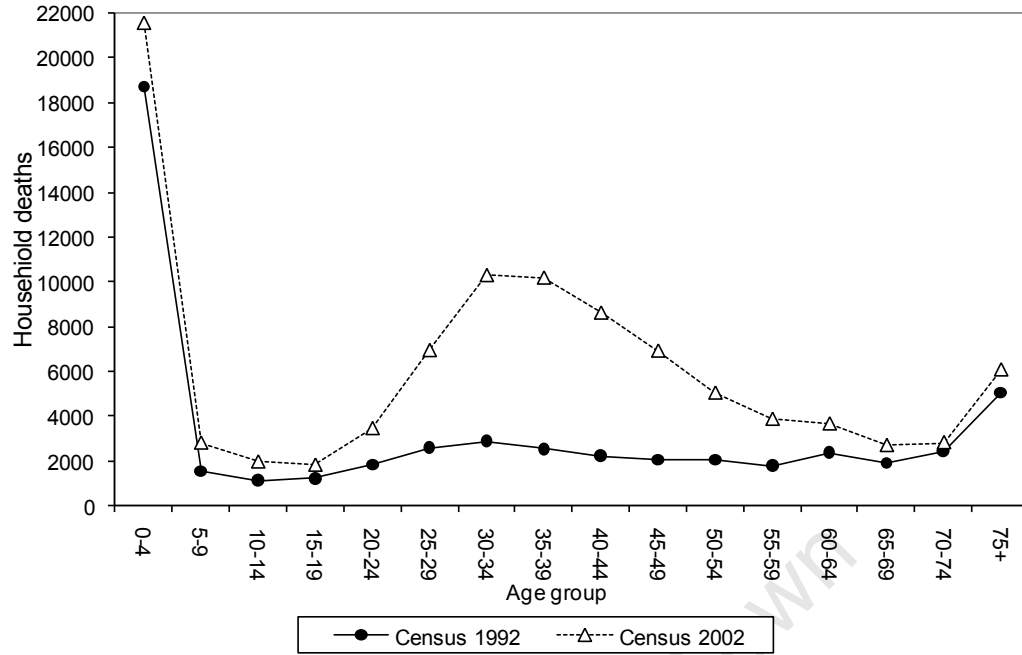


Figure 4.1 above depicts the distributions of death of females reported by households in the 1992 and 2002 censuses. The plot clearly shows a rapid increase in female deaths with over 500 per cent increase in the deaths of women aged 30-34 years. A similar trend is also apparent for male deaths as shown in Figure 4.2 below. The plots also indicate that mortality in females rises at a much younger age than that of males, with the peak mortality occurring in the age group 25-34 years in females and age group 30-39 years in males. This is consistent with what can be expected in a population experiencing a generalised HIV/AIDS epidemic.

Figure 4.2 Deaths reported by households: Males



In order to apply the GGB or SEG methods, total deaths in five-year age groups occurring in the intercensal period are required. Annual deaths for the years for which there are no data are estimated by interpolation on the assumption that deaths over the intercensal period grew exponentially. An estimate of deaths over the intercensal period is then obtained as the sum of the deaths in the intercensal period (taking note of the exact date of the censuses).

The conventional application of the death distribution methods assume, among others, that the population is closed to migration. However, for situations where migration is non-negligible both the GGB and SEG approaches can be adapted to allow for net migration (Bhat 2002; Dorrington, Timæus and Gregson 2006). In the GGB method, net migration is accommodated by adding the $nm(a+)$ component to the original Brass growth balance equation, and the result is a modified GGB equation given by $n^*(a+) - r^*(a+) + nm(a+) = a + bd^*(a+)$. Similarly, net migration, $nm(x,5)$, can be accounted for in the SEG method by subtracting the net immigration rate from the growth rate (i.e. replace the growth rate $r(x,5)$ in the original SEG method with $r(x,5) - nm(x,5)$). These adaptations to death distribution methods are of use if there are estimates of migration. These data are not readily available in Zimbabwe. As a result, it was necessary to derive some rough migration estimates to use with the method as not doing anything was likely to bias the estimates upwards.

4.2.1.1 Allowing for net migration

Net migration is estimated using the method previously used by Dorrington, Timæus and Gregson (2006). First, the standard GGB method (without taking into account net migration) is used to estimate average mortality rates by sex in five-year age groups over the intercensal period. Second, the estimated mortality rates are converted into life table survivorship ratios which are then used to project the population forward. The projections are done using the life table survivorship method (Shryock, Jacob and Associates 1976). These are calculated as:

$$\text{Forward estimate : } M1 = (I_x - E_x) = (P_x^1 - P_{x-t}^0 S_{x-t}),$$

where P_x^1 is the population aged x in the second census, P_{x-t}^0 is the population t years younger at first census and S_{x-t} is the survival factor over the intercensal period. Third, the difference between the projected population and the actual population gives an initial estimate of the age profile of the migrants. Migration is assumed to affect males aged between 15 and 54 years and females between the ages of 15 and 49 years (Dorrington, Timæus and Gregson 2006). Fourth, the proportion of migrants in each of the five-year age groups is calculated. The proportions of net migrants provide an age profile of migrants. The proportions are then multiplied by an arbitrary scalar and fed as input into the GGB. An iterative process begins in which the plots of entry minus growth rate against death rate are varied by changing the scalar. The process continues until a good fit has been achieved (i.e. most if not all of the points lie on observed straight line) and the proportion of net migrants in each five-year age group stabilises.

4.2.2 Results

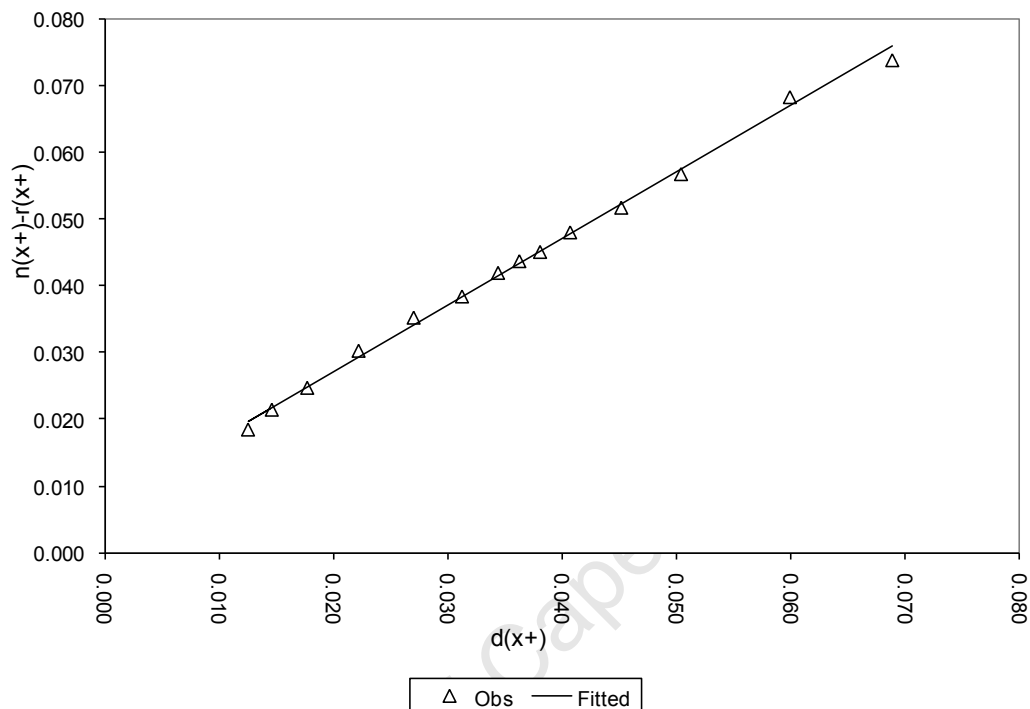
The GGB and SEG methods were applied to the three censuses conducted in the period of review. The methods applied to the 1982-1992 censuses were not adjusted for the effect of migration as it was assumed to be negligible (i.e. migration was assumed to be zero over the intercensal period). Little is known about net migration in this period. However, it is likely that there was outmigration of Whites to other countries after independence but because they are a small minority of the population, their impact on the distribution methods (at a national level) is probably negligible.

Although the return of refugees following the end of war could mean that net migration was non-negligible, it is likely that most of these refugees had returned by the time of the census in 1982, and thus not have impacted on the methods.

The results for the period 1992-2002 are based on the migration adapted GGB and SEG methods. These are the results that are described here. The results from the

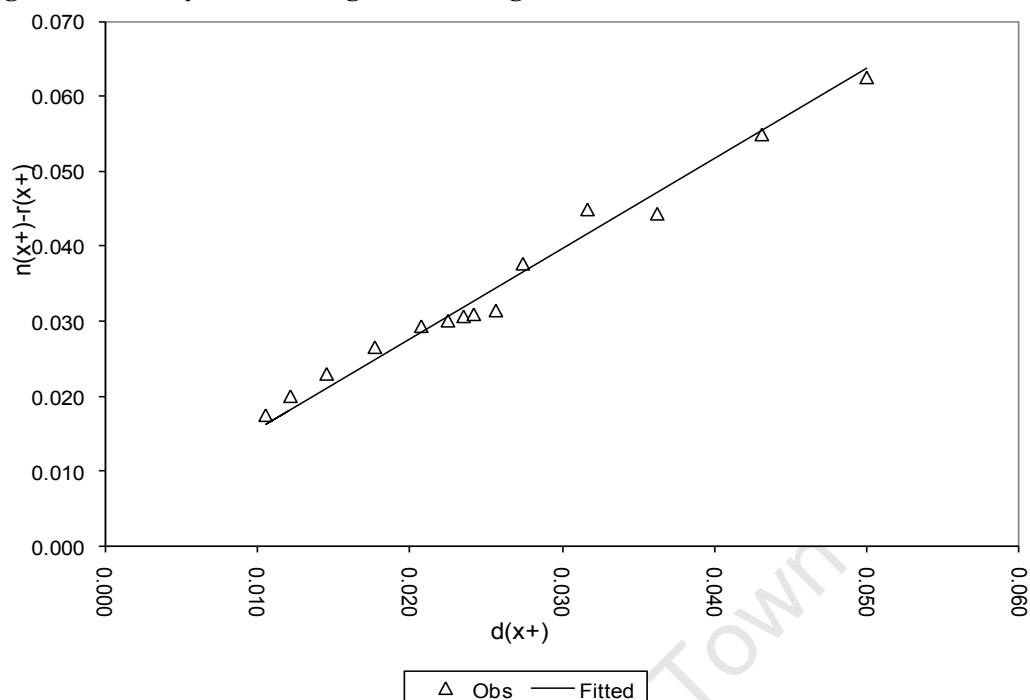
GGB analysis are best described by means of goodness of fit plots. Figure 4.3 shows the goodness of fit of the GGB (with migration) applied to the male data. The male data show a good fit. Only the highest two points show a slight deviation from the line.

Figure 4.3 Entry rate minus growth rate against death rate: Males 1992-2002



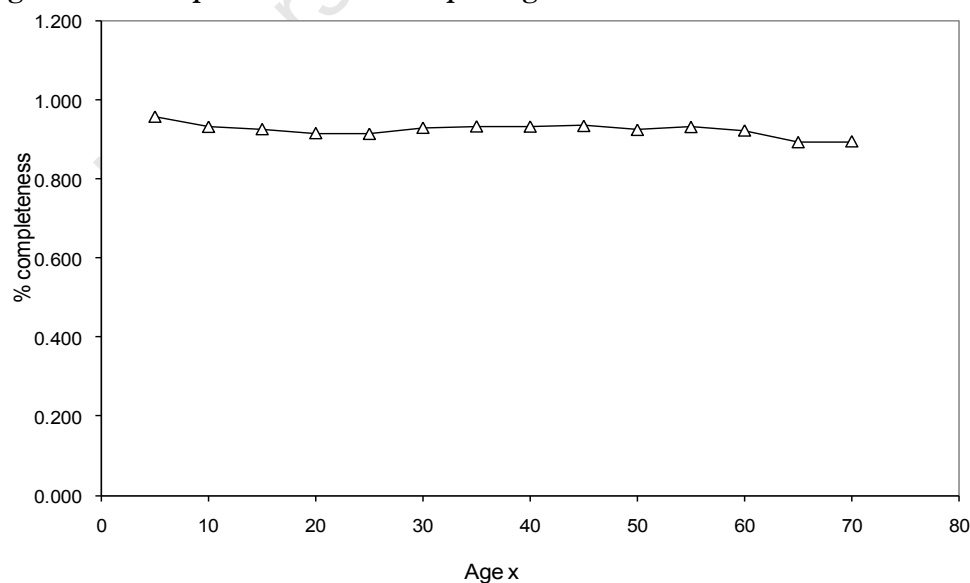
The female data, on the other hand, don't fit as well. Figure 4.4 suggests some irregularities with the data, particularly those, of young females (15+ to 50+). This might be due to failure of the net migration estimation method to estimate female migration or to inaccuracies in estimating deaths during the period from household deaths.

Figure 4.4 Entry rate minus growth rate against death rate: Females 1992-2002



After using the GGB to adjust the data for relative undercount of censuses, the adjusted data were then used in the Bennett-Horiuchi method (SEG) to estimate mortality. Figure 4.5 below shows the application of the method to estimate male mortality. The method gives completeness of death reporting of over 90 per cent for males.

Figure 4.5 Completeness of death reporting: Males 1992-2002



The application of the method to the female data is as shown in Figure 4.6. The method suggests a completeness of death reporting of about 70 per cent for females.

The completeness of death reporting for males is much higher than that of females. The reason for this is unclear but suggests that some of the assumptions underlying the estimation may be incorrect.

Figure 4.6 Completeness of death reporting: Females 1992-2002

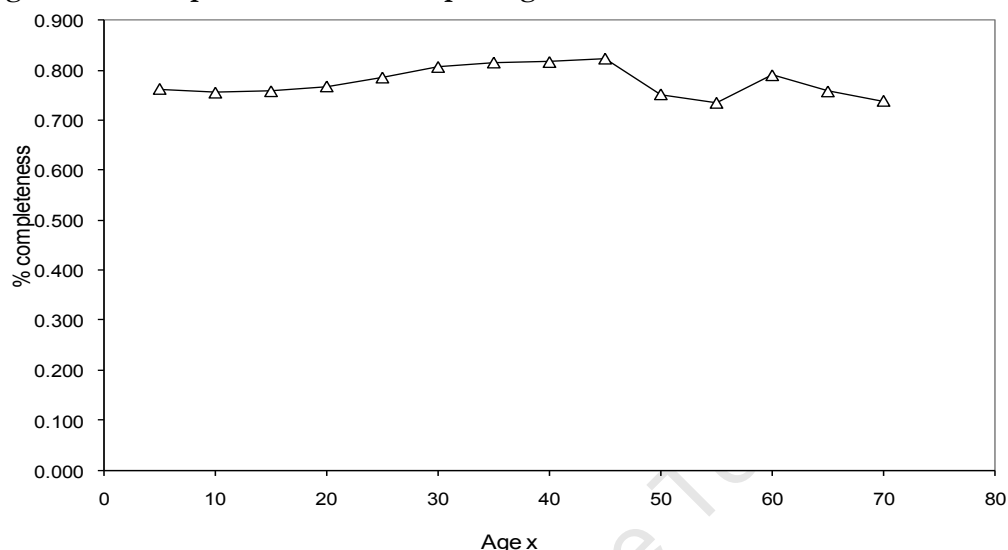


Table 4.1 Probability of dying before age 60 years for those alive at age 15 years, GGB and SEG 1982-1992

Sex	Midpoint	GGB	GGB+SEG
Male	1987.63	0.31	0.36
Female	1987.63	0.24	0.32

Table 4.1 gives the mortality estimates derived for the period 1982 to 1992 from the application of GGB method on its own and SEG used in combination with the GGB. The estimates refer to, approximately, the midpoint of the period. The analysis suggests a male adult mortality rate of 36 per cent from the combined GGB+SEG method and 31 per cent for the GGB only method. Similarly, female adult mortality rate for the year 1998 is 32 per cent for the combined GGB+SEG approach and 24 per cent for the GGB on its own. The differences between the two sets of estimates, particular for females, suggest there is some uncertainty about the estimate of the level of mortality in this period.

Table 4.2 Probability of dying before age 60 years for those alive at age 15 years, GGB and SEG 1992-2002

Sex	Midpoint	GGB	GGB+SEG
Male	1997.63	0.61	0.62
Female	1997.63	0.57	0.59

Table 4.2 gives the mortality estimates derived from the application of GGB method on its own and SEG used in combination with the GGB. The methods suggest that male and female adult mortality nearly doubled in the period 1987 to 1997. Mortality rates produced by the GGB are lower than those of the combined GGB+SEG method.

4.3 Estimates based on the survival of close relatives

Estimates here are derived from the orphanhood and sibling survivorship methods.

4.3.1 Estimates of adult mortality from the orphanhood method

Data from Zimbabwean censuses have, in the past, been used extensively to derive estimates of male and female adult mortality (Feeney 2001; Timæus and Jasseh 2004; United Nations 2002). In fact, the United Nations (2002) manual on estimating adult mortality uses data from the 1992 census in Zimbabwe to illustrate the orphanhood method. This research thus provides a means to verify those results but more importantly to rework them in light of increasing knowledge of the impact of HIV on the estimates produced by the method.

4.3.2 Data and methods

For this research, the original maternal orphanhood approach is applied individually to data from the 1982, 1992 and 2002 censuses, the 1997 intercensal survey and Demographic and Health Surveys (DHSs) of 1994, 1999 and 2005 to estimate levels and trends of female adult mortality. In addition, the two-survey method is applied to the 1982 and 1992 censuses as well as the 1992 and 2002 censuses. The paternal orphanhood method is similarly applied to the three censuses and four surveys. UNAIDS time series of antenatal HIV prevalence¹ for Zimbabwe are used to adjust for bias in the orphanhood method. The regression coefficients needed to convert proportions surviving into survivorship probabilities are those suggested by Timæus (1992:56). The survivorship probabilities are converted into a common probability of dying by using the Brass General Standard life tables. The probability of dying before reaching age 60 for those alive at age 15, ${}_{45}q_{15}$, is first estimated for those without adjustment for the impact of HIV. Then, the adjustment suggested by Timæus and Nunn (1997) will be used together with UNAIDS antenatal HIV prevalence estimates for Zimbabwe to derive female adult mortality that minimises bias. This is necessary for Zimbabwe as HIV prevalence is high and peaked in the late 1990s to early 2000s period.

¹ Data obtained through personal communication from Prof R.E. Dorrington

The results presented are only those adjusted for HIV/AIDS as well as estimates for the pre-HIV/AIDS period.

4.3.3 Results

Figure 4.7 depicts a plot of the female mortality rates obtained from the maternal orphanhood method using the two censuses and a survey. Estimates of $_{45}q_{15}$ for females from the 1982 census suggest a gradual decline in adult mortality from one death in every four adults in 1970 to about one in every five deaths at 1980. Data from the 1992 census agrees somewhat with the 1982 data but show a slight increase and a plateau in mortality in the period 1980 to around 1984. However, the estimates from the 1992 census that are closer to the census date appear implausibly low. Estimates derived from the intercensal survey, DHSs and 2002 census suggest an increasing trend in female adult mortality. The estimates from the survey are significantly higher than those from the census data with an estimate of $_{45}q_{15}$ for 1984 almost fifty per cent more than is suggested by the census. Estimates that are adjusted for HIV/AIDS selection bias are markedly higher than those unadjusted.

Figure 4.7 Probability of dying before age 60 years for those alive at age 15 years for females-Orphanhood method

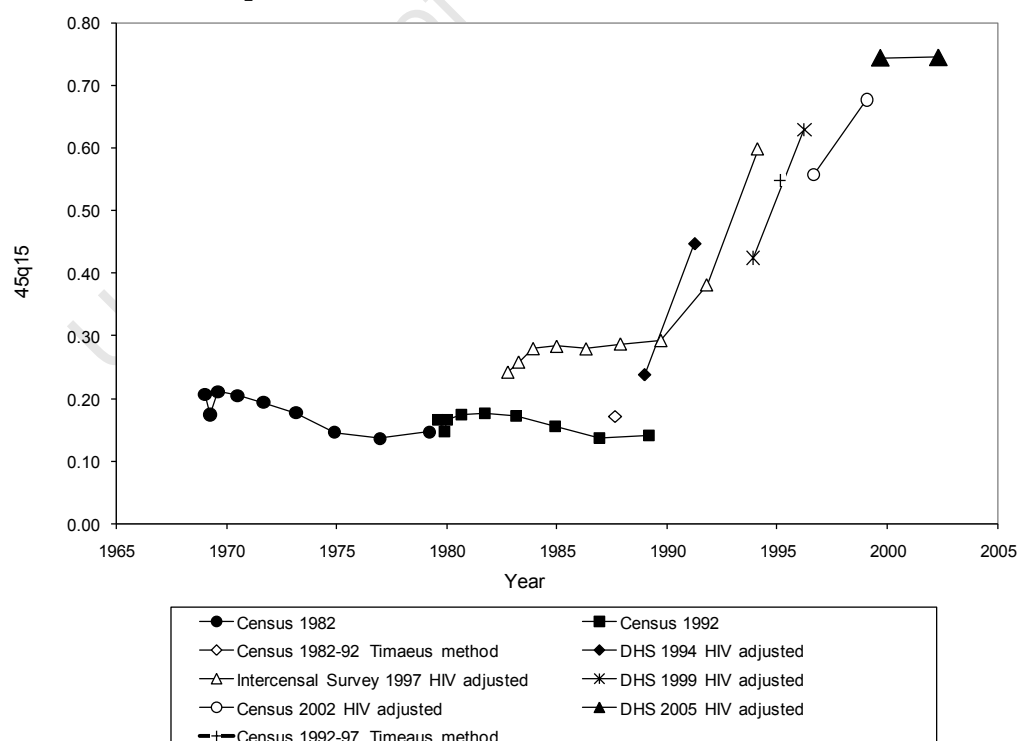
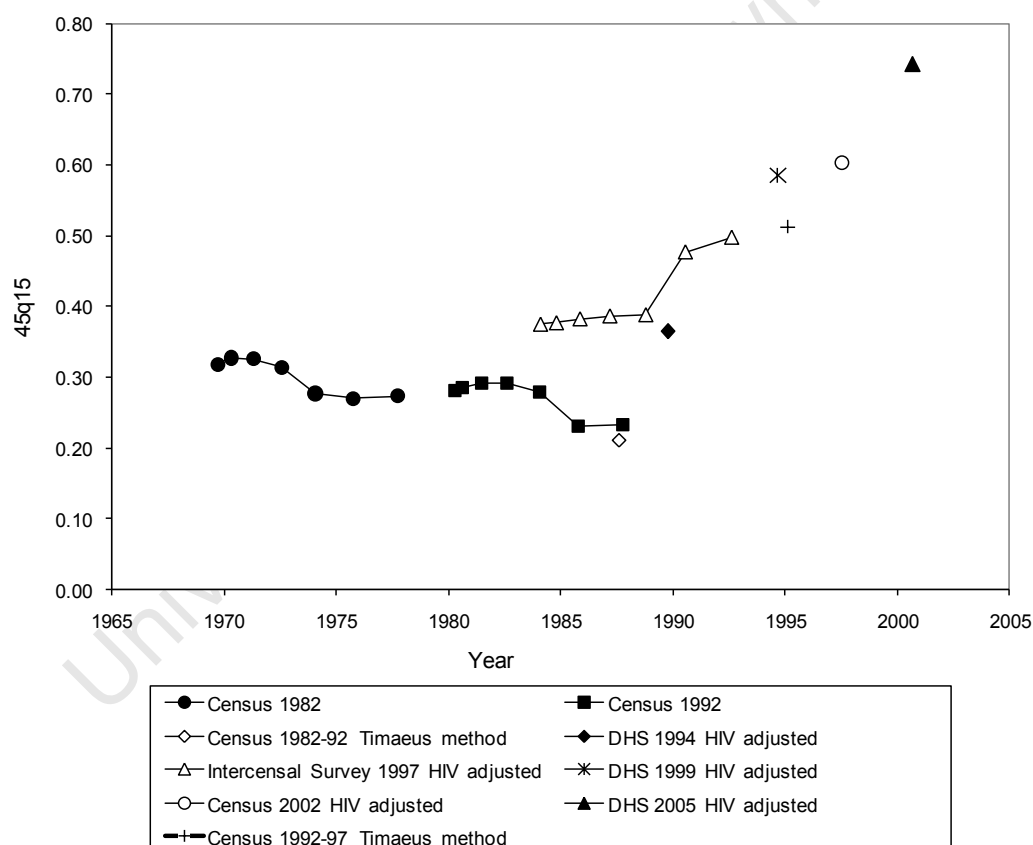


Figure 4.8 illustrates the comparison of male adult mortality from the orphanhood method. As can be expected, mortality among males is higher than that of females. The pace of mortality decline is slower for males than for females. Census data suggest a

probability of dying of slightly over one in every three men in 1970 which slows down or even stabilised to roughly under one in every three men dying by 1985. Mortality rates from the 1997 intercensal survey are, as in women, much higher than the ones from censuses and suggest an increasing trend in male adult mortality from 1985 onwards. The increasing trend in male adult mortality is backed by estimates from the DHSs and 2002 census. As in female adult mortality, estimates of ${}_{45}q_{15}$ produced by the 1992 census appear to be out of line. Feeney (2001) argues the huge discrepancies may be due to poor responses on the vital status questions in the 1992 census and 1997 intercensal survey and also the failure in the procedure used to date the estimates.

Figure 4.8 Probability of dying before age 60 years for those alive at age 15 years for males-Orphanhood method



4.3.4 Direct sibling survival method

This method is similar to the direct method of child mortality. Data from three DHS surveys (1994, 1999 and 2005) contain questions from which the information regarding the date of birth and death of the respondent's sibling can be extracted. The method was applied to reproduce published direct estimates of adult mortality in DHS reports. These were re-estimated using Stata. The direct mortality rates matched the estimates produced from the surveys (results in Appendix A). The estimates produced are only

for the ages 15 to 49 years. Using abridged life table principles, estimates of $_{35}q_{15}$ can be derived but not estimates of $_{45}q_{15}$. Table 4.3 shows the estimates of $_{35}q_{15}$ derived from the direct method. The method suggests an increase in male adult mortality from 20 percent in 1988 to almost 50 percent in 1999. Similarly, the approach suggest rising female adult mortality from 14 per cent in 1988 to 44 per cent in 1999. Since, comparisons that need to be made in this research are those for $_{45}q_{15}$, an equivalent $_{45}q_{15}$ for each value of $_{35}q_{15}$ value is derived by using the INDEPTH model life table as the standard.

Table 4.3 Probability of dying before age 50 years for those alive at age 15 years for males-Direct method DHS

Reference period	Male	Female
1988.7	0.202	0.142
1993.8	0.382	0.289
1999.9	0.493	0.442

Table 4.4 shows $_{45}q_{15}$ equivalents of $_{35}q_{15}$ produced from the direct sibling survivorship method. As a check, estimates of adult mortality were derived using the UNPD life tables as the standard. The estimates are shown in Table 4.4 below.

Table 4.4 Probability of dying before age 60 years for those alive at age 15 years for males-Direct method DHS

Reference year	Male	Female
1988.7	0.299	0.196
1993.8	0.510	0.374
1999.9	0.621	0.538

Like the estimates from the orphanhood method, the estimates from the direct sibling survivorship method suggest rising mortality risks for both males and females. Male adult mortality doubled in the ten-year period. The mortality rates for females more than doubled during this period.

Table 4.5 Probability of dying before age 60 years for those alive at age 15 years for males-Direct method DHS with UNPD life tables

Reference year	Male	Female
1988.7	0.255	0.166
1993.8	0.455	0.329
1999.9	0.593	0.486

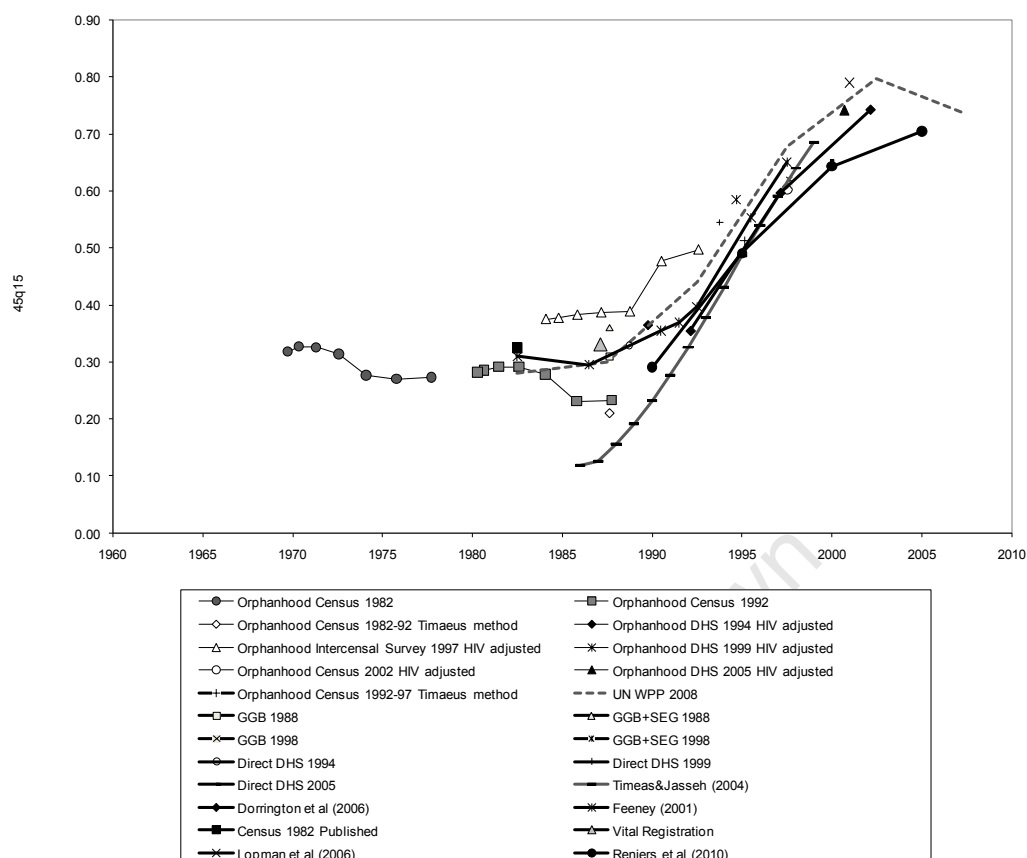
Table 4.5 shows adult mortality rates derived from the direct method and converted to standard measures using the UNPD life tables. The estimates are lower than those derived from the Brass General Standard and, by visual inspection, lower than estimates in Figure 4.8. However, they also suggest rising mortality over the period of interest.

4.4 Comparisons of adult mortality estimates

This section presents a comparison of the revised estimates against the UNPD estimates and projections as well as the estimates produced by various other researchers. It begins with a comparison on male adult mortality rates and this is followed by the comparison on female adult mortality rates.

Figure 4.9 shows the comparisons of all adult mortality rates for males. Male adult mortality rates obtained from the 1982 and 1992 censuses using the orphanhood method appear to agree with those from the UNPD except for the two youngest age groups of respondents in the 1992 census, which are lower than those of UNPD. Also the estimates of adult mortality derived from the orphanhood using 1997 intercensal survey are higher than those from UNPD. All the other revised estimates produced above tend to lie closely either above or below the UNPD. Again, direct estimates appear lower than UNPD estimates and projections. The reason for this is not clear. It may be that the DHS direct method for adult mortality might be underestimating mortality in populations affected by HIV/AIDS or that the assumptions underlying the use of the indirect methods result in overestimating the true level of mortality. The use of the Brass General Standard life table to convert conditional probabilities into common adult mortality indices result in much higher estimates of mortality than is projected by the UNPD. The General Standard life table appears not to work well for Zimbabwe. Estimates derived by other researchers are, largely, lower than both the revised estimates and UNPD estimates and projections.

Figure 4.9 Probability of dying before age 60 years for those alive at age 15 years, Males

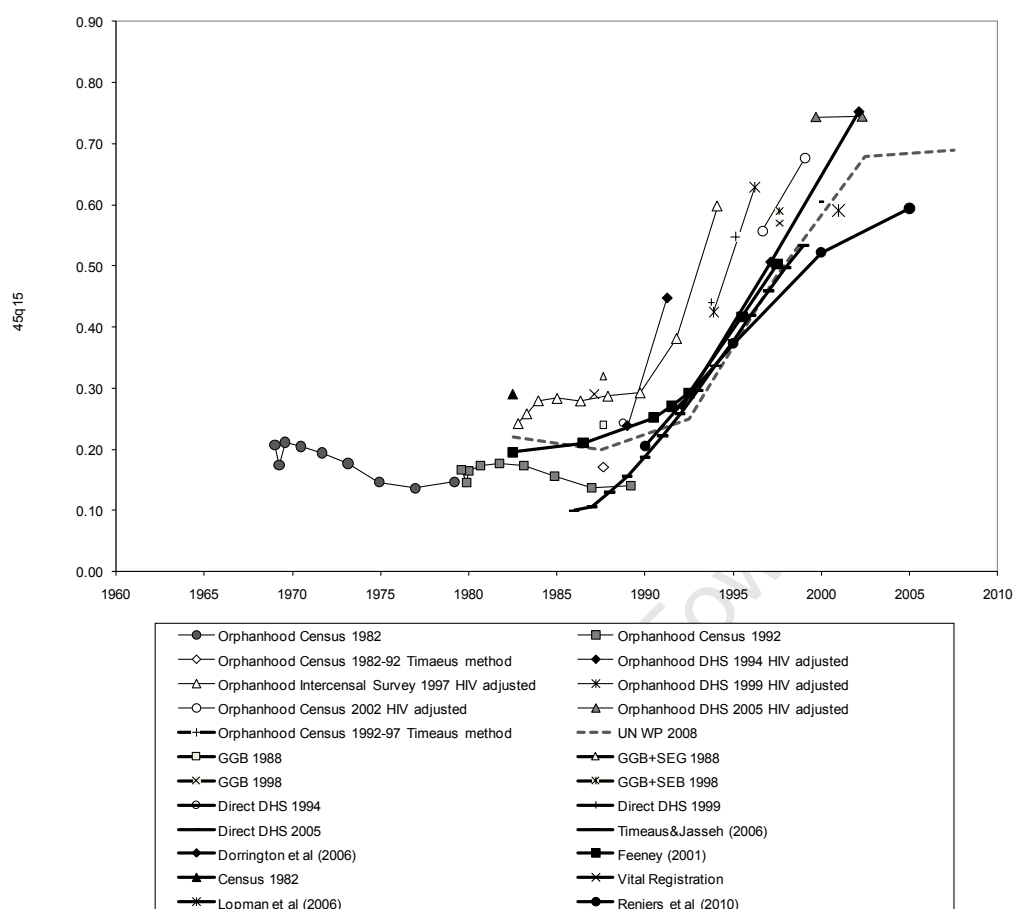


Source: (Dorrington, Timæus and Gregson 2006)²

Figure 4.10 shows how female adult mortality estimates derived from the methods used in this research compare with those produced by the UNPD as well as those from the other sources. The plot for female adult mortality suggests that the estimates from the 1982 and 1992 censuses are lower than the UNPD estimates and projections. However, the estimates of adult mortality derived for the period 1985 onwards are much higher than those of UNPD for all the methods but the two census method applied to the 1982 and 1992 census. The estimates are also much higher than those produced by other researchers. It is not clear why this is so. Perhaps, the HIV/AIDS prevalence rates used to adjust the survivorship probabilities and choice of life table used to derive these estimates might explain some of the differences. As these estimates are out of line with all the other estimates, we tested to see if changing the model life table has a big impact on the resulting estimates.

² Estimates based on Figure 4 of the paper and obtained through personal communication from Prof R.E. Dorrington.

Figure 4.10 Probability of dying before age 60 years for those alive at age 15 years, Females



Source: (Dorrington, Timæus and Gregson 2006)³

Figure 4.11 shows the recalculated male adult mortality rates based on the INDEPTH life tables and other estimates plotted alongside the UNDP estimates and projections. The plot shows that the recalculated rates are generally lower than the UNPD estimates and projections. This suggests that the choice of a life table may have a significant impact on the estimate of male adult mortality. In order to see if this impact is sex-specific, we performed the same recalculation for females.

³ Estimates based on Figure 4 of the paper and obtained through personal communication from Prof R.E. Dorrington.

Figure 4.11 Probability of dying before age 60 years for those alive at age 15 years, Males-INDEPTH model life table Pattern II

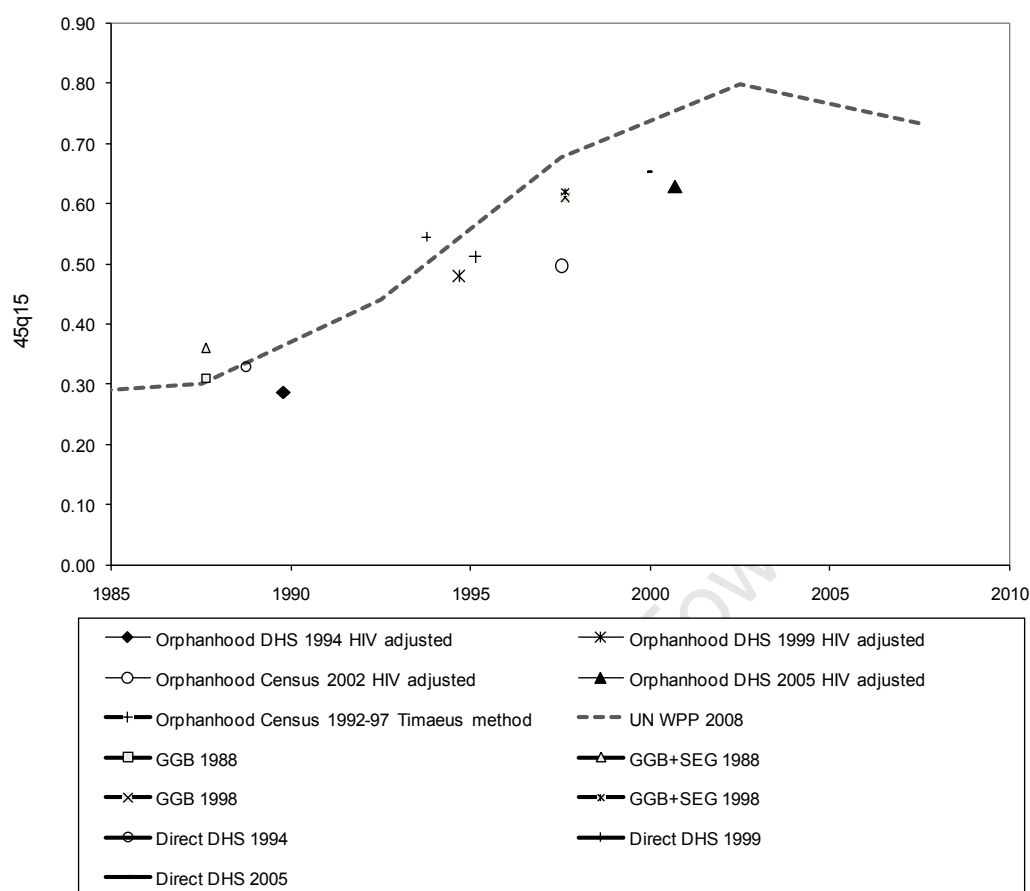
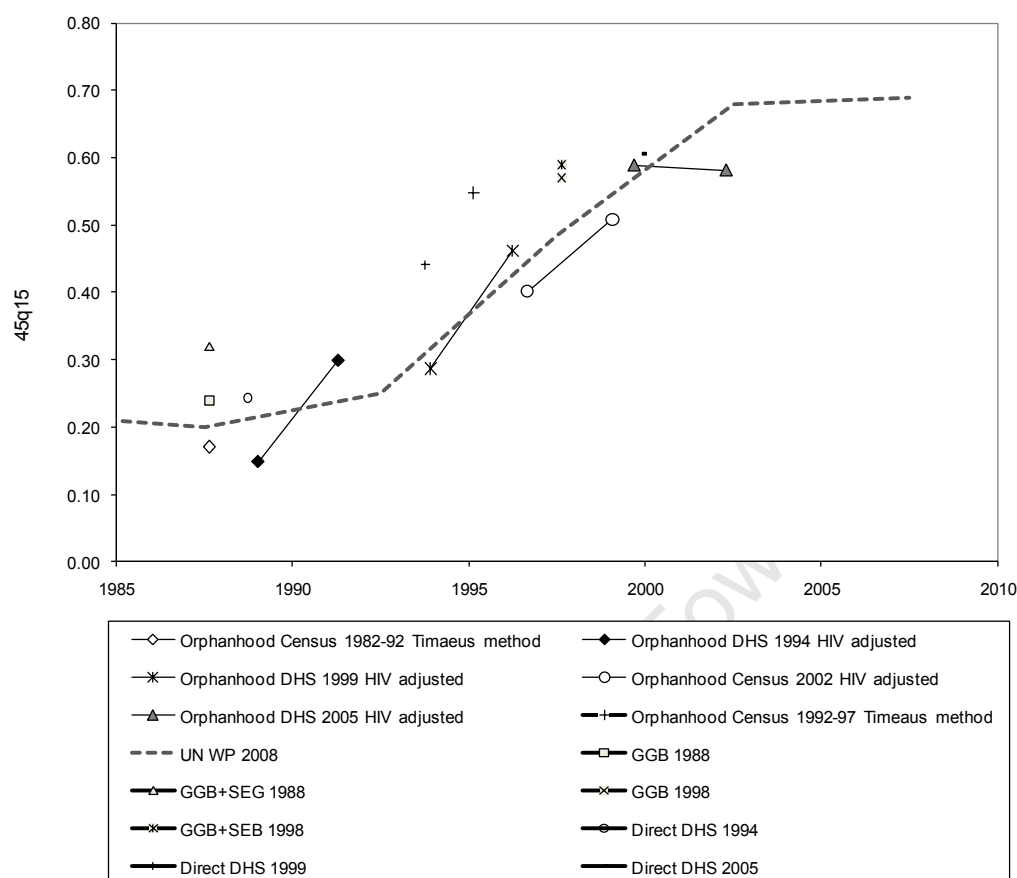


Figure 4.12 depicts the recalculated female adult mortality rates based on the INDEPTH model life tables and other adult mortality rates plotted alongside the UNPD estimates and projections. The plot shows that the recalculated rates are lower than those produced by using the Brass General Standard life tables and as a result the estimates are more consistent with the UNPD estimates and projections from UNPD. It also shows the importance of using model life tables that incorporate HIV patterns in high HIV settings such as Zimbabwe for converting rates to a standard indicator. The estimates based on INDEPTH model life tables suggest that in a population affected by HIV/AIDS, the choice of the standard is of crucial importance. It seems using a model life table which does not reflect the impact of HIV/AIDS distorts the level and trends in mortality.

Figure 4.12 Probability of dying before age 60 years for those alive at age 15 years, Females-INDEPTH model life table Pattern II



4.5 Conclusions

Overall, the adult mortality rates for both males and females show rising mortality over the period 1980 to 2005. The estimates of the probabilities of surviving to age 60 for those alive at age 15 suggests rising mortality risks in Zimbabwe from the mid-1980s to the late 1990s. This finding is consistent to past research. Male adult mortality is fairly consistent with the estimates and projections of the UNPD and the estimates produced by other researchers. Female adult mortality, on the other hand, estimated from this research is higher than UNPD. In fact, the trend in the female adult mortality shows a steeper slope than the trend for the UNPD estimates and projections. However, changing the model life table to using INDEPTH model life table seem to have had a sizeable effect on the mortality levels. Male adult mortality rates became lower than the UNPD estimates and projections. Similarly, female adult mortality rate were also lower and coincidentally resulted in mortality that is in line with UNPD estimates and projections but still higher than those from other researchers.

5 DISCUSSION AND CONCLUSIONS

The aim of the research was to derive as accurately as possible the level and trends of child and adult mortality rates by applying both direct and indirect methods to the data from the censuses and surveys conducted in the period 1980 to 2005 and to compare them with estimates derived from the World Population Prospects 2008 estimates from the UN Population Division (2009). This chapter discusses the extent to which the objectives of the study were met and identifies areas for further research. It begins with comments on the data used, then goes on to analyse the findings from child mortality as well as findings from the adult mortality. Further, it discusses the possible limitations to the study. It ends with suggestions of possible areas for future research.

The research used data from three censuses and four demographic and health surveys and an intercensal survey conducted in post-independence Zimbabwe. Published HIV prevalence rates for Zimbabwe were also used to adjust for bias in the indirect methods. The data are all representative of the population of Zimbabwe. The analysis indicates that the data are of good quality. The completeness of census reporting improved over the two intercensal periods, 1982-1992 and 1992-2002. However, the death data from the DHS 2005 survey appear to be suspect. The estimates of mortality derived from these data appear erratic and are well out of line from those of the previous surveys.

In the analysis of childhood mortality, direct and indirect methods were used. Direct estimates of child mortality were reproduced by using the method used by Macro to produce estimates from DHS data. The estimates derived matched the published estimates. The estimates show a trend similar to that of the UNPD estimates and projections but differ on level. The direct rates are markedly lower than the UNPD estimates and projections. The estimates from the DHS 2005 look particularly inconsistent with the other estimates. These rates were not adjusted for the bias due to HIV and the analysis suggests a greater impact of HIV on the estimates for the year 2005.

The indirect estimates of child mortality were corrected for bias due to HIV/AIDS using a variant of Ward and Zaba (2008) adjustment to the CEB/CS method as used by Darikwa (2009). As with direct rates, the trends of child mortality are similar to those of the UNPD estimates and projections. The estimates are, on average, higher than both the direct rates and the UNPD estimates and projections. There are

possible reasons for this. The indirect estimates, though adjusted for bias, are based on the Brass General Standard life table. This life table does not incorporate the impact of HIV on mortality. A change in the life table to the INDEPTH life table (incorporating impact of HIV), did suggest lower mortality but not enough to explain the difference in the child mortality rates. There is also the issue of the applicability of the adjustment used. If zero adjustment is used, the child mortality rates for all the years except 2005 show smooth trends while with the Darikwa (2009) method the trends are not smooth. The research is ambiguous on whether or not the adjustment proposed by Darikwa works well with Zimbabwe. The source of the differences might be in the UNAIDS prevalence rates used to derive weighted HIV/AIDS prevalence at the time when women gave birth. This is, however, not investigated further in this paper.

Unfortunately this research was not able to arrive at a conclusive estimate of the level of child mortality. The range of the estimates is wide. However, this study has shown that the standard indirect methods still have a place in estimating child mortality, albeit with some adjustments, and that more needs to be done to estimate child mortality accurately in populations that are affected by HIV.

In the analysis of adult mortality, the methods used include the death distribution methods (GGB and SEG) and methods that rely on survivorship of close relatives (orphanhood and sibling hood methods). Overall, the estimates of adult mortality suggest rising adult mortality though the magnitude of the increase varies by sex.

The estimates from the orphanhood method provide a persuasive impression of a trend in the adult mortality over the period 1980-2005. The research suggests rising mortality from the mid-1980s onwards. This finding is not new and is widely acknowledged (Dorrington, Timæus and Gregson 2006; Feeney 2001). The analysis of the trends and levels seem to point to the fact that mortality rose gradually over this period. It also suggests that adult mortality may have begun to level off. The more recent orphanhood estimates were adjusted for HIV bias using the same approach as used by Timæus and Jasseh (2004). Since these authors did not explain the rationale for the reduction factors in the method and as a result, the estimates derived from their approach may still be biased. The standard orphanhood estimates were translated into ${}_{45}q_{15}$ by using the Brass General Standard model life table while the synthetic cohort orphanhood method used life tables for Zimbabwe obtained from UNPD. Ideally, life tables derived for Zimbabwe should have been used as the standard as they would have

incorporated the impact of HIV/AIDS on mortality patterns, however, this was not done. In order to check if the choice of model life table has an effect on the estimates of adult mortality, we recalculated the mortality rates by using the INDEPTH life tables as the standard. The research shows that changing the life table has a big impact on the estimates and in fact account for most of the differences in the estimates compared to UNPD.

The adult mortality rates from the GGB and SEG methods used household deaths, as opposed to deaths from the vital registration system, to estimate adult mortality. Dorrington, Timæus and Gregson (2006) argue that the SEG used on its own may be more robust than the GGB-SEG (i.e. where the GGB is used to correct relative undercount of the censuses and the SEG uses the adjusted populations to establish mortality rates). The GGB component of the research mirrors results produced by Dorrington, Timæus and Gregson (2006). The approach yielded a better regression fit for males than for females. The research suggests a completeness of death reporting about 90 per cent for males and 70 per cent for females. To some extent this might be due to dissolution of households after the death of older women, increasing with age, leading to a misinterpretation of the slope (Dorrington, Timæus and Gregson 2006). It appears as though household deaths reported in censuses or surveys may be an alternative to vital registration data in deriving estimates of adult mortality. The quality of the diagnostic plots suggests that the methods are working well, at least for males. The research resulted in GGB estimates that are slightly different to those of Feeney (2001) using the same data in the period from 1982 to 2002.

The estimates from the direct sibling survivorship method support the findings from the indirect methods. The method suggests a doubling of adult mortality rates in the period under review. While the direct method does not require a life table conversion, we used an INDEPTH life table to convert the estimate of $_{35}q_{15}$ to an equivalent of $_{45}q_{15}$. The resulting estimates of adult mortality were higher than those produced by the UNPD. The direct estimates suffer the same problems associated with the indirect methods. Both methods depend on the accuracy of age reporting and can be affected by age heaping. The methods also suffer from completeness of death reporting. Again, it is not possible to tell the true level of adult mortality with any certainty.

As an overall conclusion, the wide range of estimates of both adult and child mortality means that accurate estimates are not possible. This research has further demonstrated, as has other past research, that the trends in mortality are indisputable. However, the level of mortality is difficult to arrive at, and it may require calibrating all the mortality estimates produced by different researchers to produce some sort of a level. Against all this, a functioning vital registration system still remains critical in order to know the true level of mortality.

There are a few possible areas for further research. First, the direct estimation of death risks from sibling data developed by Rutenberg and Sullivan (1991) is not very flexible. Regression models can be used to estimate adult mortality from DHS data (Reniers, Masquelier and Gerland 2010; Timæus and Jasseh 2004). The same approaches can be used to yield child mortality estimates for Zimbabwe. Second, Murray, Rajaratnam, Marcus *et al* (2010) recently used simulations to evaluate the performance of several variants of death distribution methods. It may be possible to use the wealth of data available in Zimbabwe to perform similar simulations to improve the estimates. Third, the work of Hallett, Gregson, Kurwa *et al* (2010) is aimed at correcting for selection bias in direct estimates of child mortality. These authors provide a stand-alone executable to estimate the bias; it would be worth trying something similar but using national data (both rural and urban) as their work was based on rural Zimbabwe data. Fourth, in a recent paper, Rajaratnam, Tran, Lopez and Murray (2010) presented various improvements to the Brass CEB/CS technique. It would be worth applying these improved methods to data from Zimbabwe. Moreover, sensitivity analyses of the indirect methods is needed to assess the impact of the choice of model life table and HIV/AIDS prevalence rates on the estimates and to understand better the levels of mortality in Zimbabwe. Lastly, while the research assessed mortality at the national level, it may be useful to estimate the level and trends of mortality in Zimbabwe by geographical strata. This would be especially useful when correcting the methods for HIV/AIDS bias. For instance, the UNAIDS Zimbabwe projections for HIV/AIDS prevalence use three different population strata (rural, urban, and other peri-urban areas) as the basis for their prevalence estimates (UNAIDS 2003). Thus, mortality rates by these strata might shed some more light on the demographic impact of HIV/AIDS in Zimbabwe. The work could also provide a basis for calibrating models such as the Actuarial Society of South Africa (ASSA) models.

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APPENDIX A: DETAILED RESULTS

This section contains results.

Table A.1 Indirect under-five mortality estimates for males, Census

Year	Census 1982	Year	Census 1992	Year	Census 2002
1981.6	179	1991.5	132	2001.6	142
1980.6	143	1990.5	109	2000.5	119
1978.4	146	1988.5	97	1998.2	113
1976.0	152	1986.4	101	1995.8	123
1973.4	153	1984.1	104	1993.1	111
1970.7	161	1981.6	118	1990.3	111
1967.7	165	1978.7	121	1987.4	118

Table A.2 Indirect under-five mortality estimates for males, DHS

Year	DHS 1988	Year	DHS 1994	Year	DHS 1999	Year	DHS 2005
1987.9	77	1993.8	82	1998.6	167	2004.8	162
1986.9	96	1992.8	126	1997.6	138	2003.8	107
1984.8	107	1990.5	101	1995.4	130	2001.5	91
1982.6	101	1988.1	104	1993.2	122	1999.2	105
1980.1	113	1985.4	90	1990.7	96	1996.6	106
1977.4	95	1982.6	101	1988.1	109	1993.8	117
1974.5	107	1979.7	101	1985.2	114	1990.9	129

Table A.3 Indirect under-five mortality estimates for females, Census

Year	Census 1982	Year	Census 1992	Year	Census 2002
1981.6	146	1991.5	135	2001.6	135
1980.6	123	1990.5	100	2000.5	109
1978.4	126	1988.5	87	1998.2	104
1976.0	133	1986.4	90	1995.8	113
1973.4	141	1984.2	93	1993.2	102
1970.7	148	1981.6	105	1990.4	104
1967.7	152	1978.7	108	1987.4	113

Table A.4 Indirect under-five mortality estimates for females, DHS

Year	DHS 1988	Year	DHS 1994	Year	DHS 1999	Year	DHS 2005
1987.9	191	1993.6	181	1998.8	138	2005.0	185
1986.9	85	1992.6	107	1997.7	115	2003.9	92
1984.8	92	1990.5	91	1995.3	117	2001.5	89
1982.6	69	1988.4	91	1992.9	96	1998.9	103
1980.1	76	1986.0	97	1990.1	87	1996.1	89
1977.4	97	1983.4	83	1987.3	83	1993.1	102
1974.4	97	1980.5	87	1984.3	93	1990.2	132

Table A.5 Indirect infant mortality estimates for males, Census

Year	Census 1982	Year	Census 1992	Year	Census 2002
1981.6	114	1991.5	82	2001.6	89
1980.6	89	1990.5	67	2000.5	74
1978.4	91	1988.5	60	1998.2	70
1976.0	96	1986.4	62	1995.8	76
1973.4	96	1984.1	64	1993.1	68
1970.7	101	1981.6	73	1990.3	69
1967.7	104	1978.7	75	1987.4	73

Table A.6 Indirect infant mortality estimates for males, DHS

Year	DHS 1988	Year	DHS 1994	Year	DHS 1999	Year	DHS 2005
1987.9	47	1993.8	50	1998.6	106	2004.8	102
1986.9	59	1992.8	78	1997.6	86	2003.8	66
1984.8	66	1990.5	62	1995.4	81	2001.5	55
1982.6	62	1988.1	64	1993.2	76	1999.2	65
1980.1	70	1985.4	55	1990.7	59	1996.6	65
1977.4	58	1982.6	62	1988.1	67	1993.8	72
1974.5	66	1979.7	62	1985.2	70	1990.9	80

Table A.7 Indirect infant mortality estimates for females, Census

Year	Census 1982	Year	Census 1992	Year	Census 2002
1981.6	91	1991.5	84	2001.6	84
1980.6	76	1990.5	61	2000.5	67
1978.4	78	1988.5	53	1998.2	64
1976.0	83	1986.4	55	1995.8	70
1973.4	88	1984.2	57	1993.2	62
1970.7	93	1981.6	64	1990.4	64
1967.7	96	1978.7	67	1987.4	70

Table A.8 Indirect infant mortality estimates for females, DHS

Year	DHS 1988	Year	DHS 1994	Year	DHS 1999	Year	DHS 2005
1987.9	122	1993.6	115	1998.8	86	2005.0	118
1986.9	52	1992.6	66	1997.7	71	2003.9	57
1984.8	56	1990.5	56	1995.3	72	2001.5	54
1982.6	42	1988.4	55	1992.9	59	1998.9	64
1980.1	46	1986.0	60	1990.1	53	1996.1	55
1977.4	59	1983.4	50	1987.3	50	1993.1	62
1974.4	59	1980.5	53	1984.3	57	1990.2	82

Table A.9 Indirect infant mortality estimates for both sexes, Census

Year	Census 1982	Year	Census 1992	Year	Census 2002
1981.6	103	1991.5	83	2001.6	86
1980.6	83	1990.5	64	2000.5	70
1978.4	85	1988.5	56	1998.2	67
1976.0	89	1986.4	58	1995.8	73
1973.4	92	1984.2	61	1993.1	65
1970.7	97	1981.6	69	1990.4	66
1967.7	100	1978.7	71	1987.4	72

Table A.10 Indirect infant mortality estimates for both sexes, DHS

Year	DHS 1988	Year	DHS 1994	Year	DHS 1999	Year	DHS 2005
1987.9	83	1993.7	87	1998.7	98	2004.9	109
1986.9	56	1992.7	72	1997.6	79	2003.9	61
1984.8	61	1990.5	59	1995.4	77	2001.5	55
1982.6	52	1988.2	60	1993.0	68	1999.0	64
1980.1	58	1985.7	57	1990.4	56	1996.3	60
1977.4	59	1983.0	57	1987.7	57	1993.5	67
1974.4	62	1980.1	59	1984.8	62	1990.6	81

Table A.11 Probability of a 15 year old male dying before age 60, DHS

Time	DHS 1994	Time	DHS 1999	Time	DHS 2005
1989.8	0.3648	1994.7	0.5851	2000.7	0.7421

Table A.12 Probability of a 15 year old female dying before age 60, DHS

Time	DHS 1994	Time	DHS 1999	Time	DHS 2005
1991.3	0.4475	1996.2	0.6290	2002.3	0.7443
1989.0	0.2382	1993.9	0.4243	1999.7	0.7436

Note: The orphanhood estimates derived from the DHS have one more data point for females (See Tables A.11 and A.12). In the paternal orphanhood method, the process of converting the proportion of respondents with father alive into conditional probabilities of survival requires chaining the two adjacent age groups together using regression coefficients. This means that data for two five-year age groups (5-9 years and 10-14 years in DHS) yields only a single estimate for male adult mortality. Thus a mortality estimate pertaining to the 5-9 year age only is possible for males. The mortality estimate corresponding to the age group 10-14 years require information about the proportion with father alive in the 15-19 years, and this information is not collected in the DHS surveys.

Table A.13 Probability of 15 year old male dying before age 60, census and intercensal survey

Time	Census 1982	Time	Census 1992	Time	Intercensal survey 1997	Time	Census 2002	Time	1982-92	Time	1992-97
1969.7	0.3180	1980.3	0.2818	1984.1	0.3751	1997.5	0.6036	1987.6	0.2102	1995.1	0.5121
1970.3	0.3269	1980.7	0.2856	1984.8	0.3771						
1971.3	0.3260	1981.5	0.2913	1985.9	0.3826						
1972.6	0.3139	1982.6	0.2913	1987.2	0.3867						
1974.1	0.2770	1984.1	0.2786	1988.8	0.3884						
1975.8	0.2701	1985.8	0.2312	1990.5	0.4767						
1977.7	0.2731	1987.8	0.2328	1992.6	0.4972						

Table A.14 Probability of 15 year old female dying before age 60, census and intercensal survey

Time	Census 1982	Time	Census 1992	Time	Intercensal survey 1997	Time	Census 2002	Time	1982-1992	Time	1992-1997
1969.0	0.2069	1979.6	0.1664	1982.8	0.2423	1996.7	0.5573	1987.6	0.1708	1995.1	0.5480
1969.2	0.1739	1979.9	0.1462	1983.3	0.2583	1999.1	0.6763				
1969.6	0.2112	1980.0	0.1654	1983.9	0.2796						
1970.5	0.2043	1980.7	0.1736	1985.0	0.2833						
1971.7	0.1938	1981.7	0.1770	1986.3	0.2793						
1973.1	0.1770	1983.2	0.1726	1987.9	0.2870						
1974.9	0.1460	1984.9	0.1555	1989.7	0.2925						
1977.0	0.1362	1987.0	0.1374	1991.8	0.3811						
1979.2	0.1466	1989.2	0.1404	1994.1	0.5974						

Table A.15 Direct adult mortality rates, DHS

Age	DHS 1994		DHS 1999		DHS 2005	
	Male	Female	Male	Female	Male	Female
15-19	0.0017	0.0021	0.0013	0.0027	0.0017	0.0027
20-24	0.0031	0.0030	0.0039	0.0055	0.0034	0.0055
25-29	0.0043	0.0045	0.0090	0.0095	0.0091	0.0122
30-34	0.0064	0.0048	0.0171	0.0131	0.0200	0.0204
35-39	0.0060	0.0056	0.0196	0.0133	0.0277	0.0250
40-44	0.0101	0.0054	0.0200	0.0126	0.0371	0.0252
45-49	0.0136	0.0054	0.0253	0.0114	0.0365	0.0255
15-49	0.0048	0.0040	0.0102	0.0086	0.0131	0.0130

APPENDIX B: STATA CODE

This section contains the Stata code used to reproduce direct rates of child mortality.

This code only yields in deaths and exposures separately and not the mortality rates. An extra step is required and, in this case, it was done in Excel.

B.1 Stata code used to verify direct rates of childhood mortality

```
//the first part of do-file extracts the deaths
```

```
use "C:\DHS Zimbabwe 2005-6 Births.dta", clear //using the child file
```

```
keep v003 v005 v008 v011 b3 b4 b5 b7 b8 //keeping the variables of interest
```

```
* Define lower limits of age categories for calculating probabilities i.e. 0, 1, 3, 6, 12, 24, 36, 48
```

```
gen agegr1 = 0
```

```
gen agegr2 = 1
```

```
gen agegr3 = 3
```

```
gen agegr4 = 6
```

```
gen agegr5 = 12
```

```
gen agegr6 = 24
```

```
gen agegr7 = 36
```

```
gen agegr8 = 48
```

```
gen agegr9 = 60
```

```
* Set width of each period for analysis (in months), the program works for minimum period of twelve months
```

```
gen period = 60
```

```
* Set number of periods for analysis
```

```
gen maxper = 6
```

```
* Set upper and lower limits for date of analysis period
```

```
gen upplim = v008 - 1
```

```
gen lowlim = v008 - (maxper * period) - 1
```

```
* Select only dead children born in the periods of analysis
```

```
gen xproc = 0
```

```
replace xproc = 1 if (lowlim <= b3 & b3 <= upplim & b5 == 0)
```

```
keep if xproc == 1
```


* Assign deaths to age groups. Note that for compatibility with WFS surveys, once deaths are assigned to an age group, only the information on the age group of death is used NOT the actual age at death

gen j=0

replace j=1 if (agegr1 <= b7 & b7 < agegr2) // Age at death = 0 months

replace j=2 if (agegr2 <= b7 & b7 < agegr3) // Age at death = 1-2 months

replace j=3 if (agegr3 <= b7 & b7 < agegr4) // Age at death = 4-5 months

replace j=4 if (agegr4 <= b7 & b7 < agegr5) // Age at death = 6-11 months

replace j=5 if (agegr5 <= b7 & b7 < agegr6) // Age at death = 12-23 months

replace j=6 if (agegr6 <= b7 & b7 < agegr7) // Age at death = 24-35 months

replace j=7 if (agegr7 <= b7 & b7 < agegr8) // Age at death = 36-47 months

replace j=8 if (agegr8 <= b7 & b7 < agegr9) // Age at death = 48-59 months

gen agedth = j - 1.

keep if (j != 0) //Select children who died under age 5

gen perborn = trunc((v008-1 - b3)/period) // Determine period of birth and death

gen limlow = v008 - (perborn+1) * period // Calculate lower bound for the date of the period in which the child was born (limlow)

* Calculate earliest date death could occur in age group j

gen agei=.

replace agei = b3 + agegr1 if (j == 1) // ie Month of birth

replace agei = b3 + agegr2 if (j == 2) // ie month of birth + 1 month

replace agei = b3 + agegr3 if (j == 3) // ie month of birth + 3 months

replace agei = b3 + agegr4 if (j == 4) // ie month of birth + 6 months

replace agei = b3 + agegr5 if (j == 5) // ie month of birth + 12 months

replace agei = b3 + agegr6 if (j == 6) // ie month of birth + 24 months

replace agei = b3 + agegr7 if (j == 7) // ie month of birth + 36 months

replace agei = b3 + agegr8 if (j == 8) // ie month of birth + 48 months

* Calculate date of start of next age group (i.e. upper bound on date of death in age group j)

gen nxtage=.

replace nxtage = b3 + agegr2 if (j == 1) // ie Month of birth + 1 month

replace nxtage = b3 + agegr3 if (j == 2) // ie month of birth + 3 months

replace nxtage = b3 + agegr4 if (j == 3) // ie month of birth + 6 months

replace nxtage = b3 + agegr5 if (j == 4) // ie month of birth + 12 months

replace nxtage = b3 + agegr6 if (j == 5) // ie month of birth + 24 months

replace nxtage = b3 + agegr7 if (j == 6) // ie month of birth + 36 months

replace nxtage = b3 + agegr8 if (j == 7) // ie month of birth + 48 months

replace nxtage = b3 + agegr9 if (j == 8) // ie month of birth + 60 months

* Calculate upper bound for the date of the period in which the child was born (limupp)

```

gen limupp = limlow + period
gen n = 1

* number of periods in which death could occur
gen iter = 0

* Death occurs in same period of birth
replace iter = 1 if (limlow <= b3 & nxtage <= limupp)

* Death could occur in period of birth or in the next period
replace iter = 2 if (agei < limupp & limupp <= nxtage)

* Death occurs in period after birth *.
replace iter = 1 if (b3 < limupp & limupp <= agei)

* Set perborn to period of death, i.e. next period *.
replace perborn = perborn - 1 if (b3 < limupp & limupp <= agei)

* All deaths to children born in the most recent period must occur in the most recent period
replace iter = 1 if (perborn == 0)
replace n = n / iter if (iter != 0)

* Colper defines columns for table = time periods
gen colper = perborn

* Weight the data. Deaths that could have occurred in either of two time periods are assigned 1/2 to each
period (n)
gen rweight = n * v005/1000000
save "C:\mort.dta", replace
clear

use "C:\mort.dta", clear

* Tabulate deaths that occurred to children born in the last 5 periods by age at death and period ;
procedure output outfile='deaths1.tmp'.
gen xtabs = 0
replace xtabs = 1 if (iter != 0 & 0 <= colper & colper < 5)
tab agedth colper[iweight=rweight] if (xtabs == 1)
tab agedth colper[iweight=rweight] if (xtabs == 1 & b4==1)
tab agedth colper[iweight=rweight] if (xtabs == 1 & b4==2)
clear

```

```

use "C:\mort.dta", clear
* Retabulate deaths that could have occurred in the next period, in that period; procedure output
outfile='deaths2.tmp'.
replace colper = colper - 1 if (iter == 2)
gen xtabs = 0
replace xtabs = 1 if (iter == 2 & 0 <= colper & colper < 5)
tab agedth colper [iweight=rweight] if (xtabs == 1)
tab agedth colper [iweight=rweight] if (xtabs == 1 & b4==1)
tab agedth colper [iweight=rweight] if (xtabs == 1 & b4==2)

*****

//this second part estimates the exposure to risk of dying (denominators)
use "C:\ DHS Zimbabwe 2005-6 Births.dta", clear //using the child file
keep v003 v005 v008 v011 b3 b4 b5 b7 b8 //keeping the variables of interest

* Set width of each period for analysis. Minimum = 12 months
gen period = 60
* Set number of periods for analysis
gen maxper = 6

* Define lower limits of age categories for calculating probabilities *
gen agegr1 = 0
gen agegr2 = 1
gen agegr3 = 3
gen agegr4 = 6
gen agegr5 =12
gen agegr6 =24
gen agegr7 =36
gen agegr8 =48
gen agegr9 =60

* Set upper and lower limits for date of analysis period
gen upplim = v008 - 1
gen lowlim = v008 - (maxper * period) - 1

* Select children born in the analysis period
gen xproc = 0
replace xproc = 1 if (lowlim <= b3 & b3 <= upplim)
keep if (xproc == 1)

* Set months = number of months child lived

```

```

gen months = 0
replace months = b7 if (b5 == 0)
replace months = (v008 - b3) if (b5 == 1)

* Calculate period of birth
gen perborn = trunc((v008-1 - b3)/period)
save "C:\child2.dta", replace
clear

* Tabulate exposure in the first age group (0 months) by period
use "C:\child2.dta"
gen ageexp = 0
gen agei = b3 //set agei to CMC for start of age group
gen nxtage = b3 + agegr2 //next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear

* Tabulate exposure in the second age group (1-2 months) by period
use "C:\child2.dta"
gen ageexp = 1
gen agei = b3 + agegr2 //set agei to CMC for start of age group
gen nxtage = b3 + agegr3 //set next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear

* Tabulate exposure in the third age group (3-5 months) by period *
use "C:\child2.dta"
gen ageexp = 2
gen agei = b3 + agegr3 //set agei to CMC for start of age group
gen nxtage = b3 + agegr4 //set next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear

* Tabulate exposure in the fourth age group (6-11 months) by period
use "C:\child2.dta"

```

```

gen ageexp = 3
gen agei = b3 + agegr4 //set agei to CMC for start of age group
gen nxtage = b3 + agegr5 //set next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear

```

* Tabulate exposure in the fifth age group (12-23 months) by period

```

use "C:\child2.dta"
gen ageexp = 4
gen agei = b3 + agegr5 //set agei to CMC for start of age group
gen nxtage = b3 + agegr6 //set next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear

```

* Tabulate exposure in the sixth age group (24-35 months) by period

```

use "C:\child2.dta"
gen ageexp = 5
gen agei = b3 + agegr6 //set agei to CMC for start of age group
gen nxtage = b3 + agegr7 //set next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear

```

* Tabulate exposure in the seventh age group (36-47 months) by period

```

use "C:\child2.dta"
gen ageexp = 6
gen agei = b3 + agegr7 //Set agei to CMC for start of age group
gen nxtage = b3 + agegr8 //set next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear

```

* Tabulate exposure in the eighth age group (48-59 months) by period

```

use "C:\child2.dta"

```

```

gen ageexp = 7
gen agei = b3 + agegr8 //set agei to CMC for start of age group
gen nxtage = b3 + agegr9 //set next age to CMC for start of next age group
do "C:\mort_2.do"
do "C:\mort_3.do"
do "C:\mort_4.do"
clear
*****

//this part contains sub-programs used in calculating exposure

mort2.do
* Define the period of birth of the child and the number of iterations

* Select children exposed for at least part of the age group ie children who enter the age group
keep if (agei <= b3 + months)

* Calculate lower bound for the date of the period in which the child was born
gen limlow = v008 - ((perborn+1) * period)

* Calculate upper bound for the date of the period in which the child was born
gen limupp = limlow + period

* Determine number of periods in which exposure occurred in the age group (iter)
gen iter = 0
replace perborn = perborn - 1 if (limupp <= agei)
replace iter = 1 if (limupp <= agei)
replace n = 1 if (limupp <= agei)
replace limlow = limlow + period if (limupp <= agei)
replace limupp = limlow + period if (limupp <= agei)

* All exposure occurs in period of birth *
replace iter = 1 if (nxtage < limupp)
replace n = 1 if (nxtage < limupp)

* Exposure occurs in period of birth and in the next period *
replace iter = 2 if (agei < limupp & limupp <= nxtage)
replace n = 0.5 if (agei < limupp & limupp <= nxtage)
replace iter = 1 if (agei < limupp & limupp <= nxtage & perborn == 0)

* Colper defines columns for tabulation = time periods
gen colper = perborn

```

```

* Weight data. Division by 100 used to all more decimal places in the tabulation. Exposure that occurs
over two time periods is assigned 1/2 to each period (n)
gen rweight = n * v005/1000000

```

```

* Select 5 periods for tabulation
replace xproc = 0
replace xproc = 1 if (0 <= colper & colper < 5)

```

```

mort3.do
*Tabulate the first part of the exposure
keep if (xproc == 1)
tab ageexp colper [iweight=rweight]
tab ageexp colper [iweight=rweight] if b4==1
tab ageexp colper [iweight=rweight] if b4==2

```

```

* Prepare for the second part of the tabulation
replace colper = colper - 1
replace xproc = 0
replace xproc = 1 if (0 <= colper & colper <= 4 & iter == 2)

```

```

mort4.do
* Tabulate the second part of the exposure
keep if (xproc == 1)
tab ageexp colper[iweight=rweight]
tab ageexp colper[iweight=rweight] if b4==1
tab ageexp colper[iweight=rweight] if b4==2

```

B.2 Stata code used to verify direct rates of adult mortality rates

This section contains the Stata code used to reproduce direct rates of adult mortality based on the siblinghood method. This code only yields in deaths and exposures separately and not the mortality rates. An extra step is required, in this case, it was done in Excel

```

use "C:\Sibling Death Data.dta"
*****
gen doi =v008
gen aad1= dod-1-dob //age at death, in months

```

```

gen aad6=(dod-61)-dob //age at death for siblings dying 60 months before the interview
gen age84=(doi-85)-dob //sibling age 84 months before the interview
gen aadyrs = int((dod-dob)/12) if status==0 //age last birthday at death
gen yasd1 = int((v008-dod)/12) if status==0 //years ago since death
gen age5d=trunc((dod-1-dob)/60) if status==0 // highest age group in which the person died

*****

/* create variables to store person-years of exposure for dead siblings where letters before the underscore:
'h' refers the age group at death at the time of survey, 'm' refers to the age group next to the age group at
the time of the survey & 'l' denotes the third age group down from the age group at death at the time of
the survey*/
gen h_expd=0
gen m_expd=0
gen l_expd=0
*****

gen agei= (doi-1)-dob //age of siblings if all had they survived to interview date
gen age5s= trunc((doi-1-dob)/60) //highest (current) age group
gen m_age5s=trunc((doi-61-dob)/60) //middle (next) age group
replace m_age5s=99 if age5s<1 //set the middle age group to 99 for implausible age group
gen l_age5s=m_age5s-1 //lowest(next to middle)age group
replace l_age5s=99 if m_age5s<1 | m_age5s==99 //set the lowest age group to 99 for implausible age
group

//labelling the age groups
label variable age5s `five-year age groups'
label define age5s 0"0-4" 1"5-9" 2"10-14" 3"15-19" 4"20-24" 5"25-29" 6"30-34" 7"35-39" 8"40-44" 9"45-
49" 10"50-54" 11"55-59" 12"60-64" 13"65-69" 14"70-74"
label values age5s age5s

label variable m_age5s `five-year age groups'
label define m_age5s 0"0-4" 1"5-9" 2"10-14" 3"15-19" 4"20-24" 5"25-29" 6"30-34" 7"35-39" 8"40-44"
9"45-49" 10"50-54" 11"55-59" 12"60-64" 13"65-69" 14"70-74"
label values m_age5s m_age5s

label variable l_age5s `five-year age groups'
label define l_age5s 0"0-4" 1"5-9" 2"10-14" 3"15-19" 4"20-24" 5"25-29" 6"30-34" 7"35-39" 8"40-44"
9"45-49" 10"50-54" 11"55-59" 12"60-64" 13"65-69" 14"70-74"
label values l_age5s l_age5s

gen h_exps=0 //variable to store high age group exposure
gen m_exps=0 //variable to store middle age group exposure

```



```

gen l_exps=0 //variable to store lowest age group exposure

*****

/* exposure if all siblings had survived to interview date */
replace h_exps=((doi-1)-dob)-(age5s*60)+1 //exposure (in months) at the current age group is given by
the difference between age at interview and lower limit of the age group
replace m_exps=60 if h_exps<=24
replace m_exps=84-h_exps if h_exps>24
replace l_exps=84-(h_exps+ m_exps) if h_exps+m_exps<84 //if the exposure (in months) in the two
previous age groups is less than 84 months, then exposure is estimated for the next to the middle age
group replace l_exps=0 if h_exps+m_exps>=84 //removes exposure where it goes out of the period of
analysis.

/* weights for surviving siblings */
gen expo1s=h_exps*weight
gen expo2s=m_exps*weight
gen expo3s=l_exps*weight

*****

/* exposure for siblings dead only */
gen lostexpo=doi-1-dod //exposure lost due to death

// calculating exposure if the death occurred in the highest age group
replace h_expd=84-(lostexpo+m_exps+l_exps) if age5d==age5s
replace m_expd=m_exps if age5d==age5s
replace l_expd=l_exps if age5d==age5s

// calculating exposure if the death occurred in the middle age group
replace h_expd=0 if age5d==m_age5s
replace m_expd= 84-(lostexpo+l_exps) if age5d==m_age5s
replace l_expd=l_exps if age5d==m_age5s

// calculating exposure if the death occurred in the lowest age group
replace h_expd=0 if age5d==l_age5s
replace m_expd=0 if age5d==l_age5s
replace l_expd=84-lostexpo if age5d==l_age5s

/* weights for dead siblings */
gen expo1d=h_expd*weight
gen expo2d=m_expd*weight
gen expo3d=l_expd*weight

```

```
browse aad aad1 yasd1 dod dob h_exps m_exps l_exps h_expd m_expd l_expd age5d age5s m_age5s  
l_age5s expo1d expo2d expo3d if status==0 & yasd1>=0 & yasd1<7
```

```
/* Output: exposure for dead siblings by sex from highest age group (had they survived) at the time of  
survey */
```

```
tab age5s sex [iweight=expo1d] if status==0 & expo1s>0 & h_expd>0 & age5s>2 & age5s<10 &  
yasd1>=0 & yasd1<7,miss
```

```
/* Output: exposure for dead siblings by sex from middle age group at the time of survey */
```

```
tab m_age5s sex [iweight=expo2d] if status==0 & expo2s>0 & m_expd>0 & m_age5s>2 & m_age5s<10  
& yasd1>=0 & yasd1<7,miss
```

```
/* Output: exposure for dead siblings by sex from lowest age group at the time of survey */
```

```
tab l_age5s sex [iweight=expo3d] if status==0 & expo3s>0 & l_expd>0 & l_age5s>2 & l_age5s<10 &  
yasd1>=0 & yasd1<7,miss
```

```
/* Output: exposure for surviving siblings by sex from highest age group at the time of survey */
```

```
tab age5s sex [iweight=expo1s] if status==1 & expo1s>0 & h_exps>0 & age5s>2 & age5s<10,miss
```

```
/* Output: exposure for surviving siblings by sex from middle age group at the time of survey */
```

```
tab m_age5s sex [iweight=expo2s] if status==1 & expo2s>0 & m_exps>0 & m_age5s>2 &  
m_age5s<10,miss
```

```
/* Output: exposure for surviving siblings by sex from lowest age group at the time of survey */
```

```
tab l_age5s sex [iweight=expo3s] if status==1 & expo3s>0 & l_exps>0 & l_age5s>2 & l_age5s<10,miss
```

APPENDIX C: APPLICATION OF THE INDIRECT BRASS CEB/CS METHOD WITH WARD AND ZABA ADJUSTMENT TO ZIMBABWE: 1982

This section contains some of the computation tables.

C.1

Age group	Number of women	CEB Male	Female	CS Male	Female	TCEB	TCS	Sex Ratio CEB	TCD	TCD Male	TCD Female
15-19	412,610	47,720	46,340	42,730	42,490	94,060	85,220	1.0298	8,840	4,990	3,850
20-24	364,200	267,500	266,540	237,520	241,150	534,040	478,670	1.0036	55,370	29,980	25,390
25-29	281,060	430,050	431,270	372,740	381,690	861,320	754,430	0.9972	106,890	57,310	49,580
30-34	206,760	483,610	478,410	410,110	414,790	962,020	824,900	1.0109	137,120	73,500	63,620
35-39	170,170	502,940	497,320	419,970	421,910	1,000,260	841,880	1.0113	158,380	82,970	75,410
40-44	139,530	479,840	469,280	391,270	389,470	949,120	780,740	1.0225	168,380	88,570	79,810
45-49	110,390	400,580	392,940	316,630	316,780	793,520	633,410	1.0194	160,110	83,950	76,160
Total	1,684,720	2,612,240	2,582,100	2,190,970	2,208,280	5,194,340	4,399,250		795,090	421,270	373,820

Average parities per woman, by sex and age of mother

Age group	index	Average parities			proportions dead-D(i)		
		Male	Female	Both	Male	Female	Both
15-19	1	0.11565	0.11231	0.22796	0.10457	0.08308	0.09398
20-24	2	0.73449	0.73185	1.46634	0.11207	0.09526	0.10368
25-29	3	1.53010	1.53444	3.06454	0.13326	0.11496	0.12410
30-34	4	2.33899	2.31384	4.65283	0.15198	0.13298	0.14253
35-39	5	2.95552	2.92249	5.87800	0.16497	0.15163	0.15834
40-44	6	3.43897	3.36329	6.80226	0.18458	0.17007	0.17741
45-49	7	3.62877	3.55956	7.18833	0.20957	0.19382	0.20177

Calculation of multipliers-k(i)=a(i)+b(i).P(1)/P(2)+c(i). P(2)/P(3)

Age group	index	multipliers k(i) for		
		Male	Female	Both
15-19	1	1.0831	1.0916	1.0873
20-24	2	1.0450	1.0480	1.0465
25-29	3	0.9946	0.9956	0.9951
30-34	4	1.0038	1.0042	1.0040
35-39	5	1.0165	1.0167	1.0166
40-44	6	1.0090	1.0091	1.0090
45-49	7	1.0012	1.0013	1.0013
P(1)/P(2)		0.1575	0.1535	0.1555
P(2)/P(3)		0.4800	0.4769	0.4785

Estimation of time reference period $t(x)=a(i)+b(i).P(1)/P(2)+c(i). P(2)/P(3)$

age group	age x	parameter	reference period-t(x)			average date
		estimate	male	female	both sexes	of survey
15-19	1	q1	1.01	1.00	1.01	1982.63
20-24	2	q2	2.04	2.02	2.03	
25-29	3	q3	4.28	4.26	4.27	
30-34	5	q5	6.62	6.60	6.61	
35-39	10	q10	9.21	9.19	9.20	
40-44	15	q15	11.96	11.95	11.95	
45-49	20	q20	14.90	14.89	14.89	

Calculation of probabilities of dying $q(x)=k(i)*D(i)$							
Age group	age (x)	Male		Female		Both	
		q(x)	Referen q(x)	Referen q(x)	Referen q(x)	Reference date	
15-19	1	0.1133	1981.6	0.0907	1981.6	0.1022	1981.6
20-24	2	0.1171	1980.6	0.0998	1980.6	0.1085	1980.6
25-29	3	0.1325	1978.4	0.1145	1978.4	0.1235	1978.4
30-34	5	0.1526	1976.0	0.1335	1976.0	0.1431	1976.0
35-39	10	0.1677	1973.4	0.1542	1973.4	0.1610	1973.4
40-44	15	0.1862	1970.7	0.1716	1970.7	0.1790	1970.7
45-49	20	0.2098	1967.7	0.1941	1967.7	0.2020	1967.7

Calculation Ward&Zaba adjustments									
HIV Prev at ref year			Male		Female		Both		
Male	Female	Both	W&Z addition	q(x) adjusted	W&Z additions	q(x) adjusted	W&Z additions	q(x) adjusted for HIV	
0.8%	0.8%	0.8%	0.00039	0.1136	0.00039	0.0911	0.00039	0.1026	
0.5%	0.5%	0.5%	0.00035	0.1175	0.00035	0.1002	0.00035	0.1088	
0.0%	0.0%	0.0%	0.00000	0.1325	0.00000	0.1145	0.00000	0.1235	
0.0%	0.0%	0.0%	0.00000	0.1526	0.00000	0.1335	0.00000	0.1431	
0.0%	0.0%	0.0%	0.00000	0.1677	0.00000	0.1542	0.00000	0.1610	
0.0%	0.0%	0.0%	0.00000	0.1862	0.00000	0.1716	0.00000	0.1790	
0.0%	0.0%	0.0%	0.00000	0.2098	0.00000	0.1941	0.00000	0.2020	

Converting into common mortality index													
Estimated					Estimated					Estimated			
Survivorshi	l(x)	Alpha	Beta	5q0	l(x)	Alpha	Beta	5q0	l(x)	Alpha	Beta	5q0	
q(1)	0.8864	-0.1597	1.0000	0.1790	0.9089	-0.2830	1.0000	0.1456	0.8974	-0.2171	1.0000	0.1627	
q(2)	0.8825	-0.2930	1.0000	0.1431	0.8998	-0.3823	1.0000	0.1225	0.8912	-0.3360	1.0000	0.1329	
q(3)	0.8675	-0.2829	1.0000	0.1456	0.8855	-0.3665	1.0000	0.1260	0.8765	-0.3234	1.0000	0.1358	
q(5)	0.8474	-0.2560	1.0000	0.1524	0.8665	-0.3337	1.0000	0.1334	0.8569	-0.2935	1.0000	0.1429	
q(10)	0.8323	-0.2517	1.0000	0.1535	0.8458	-0.3019	1.0000	0.1409	0.8390	-0.2762	1.0000	0.1472	
q(15)	0.8138	-0.2247	1.0000	0.1607	0.8284	-0.2745	1.0000	0.1477	0.8210	-0.2489	1.0000	0.1542	
q(20)	0.7902	-0.2080	1.0000	0.1652	0.8059	-0.2569	1.0000	0.1522	0.7980	-0.2318	1.0000	0.1587	